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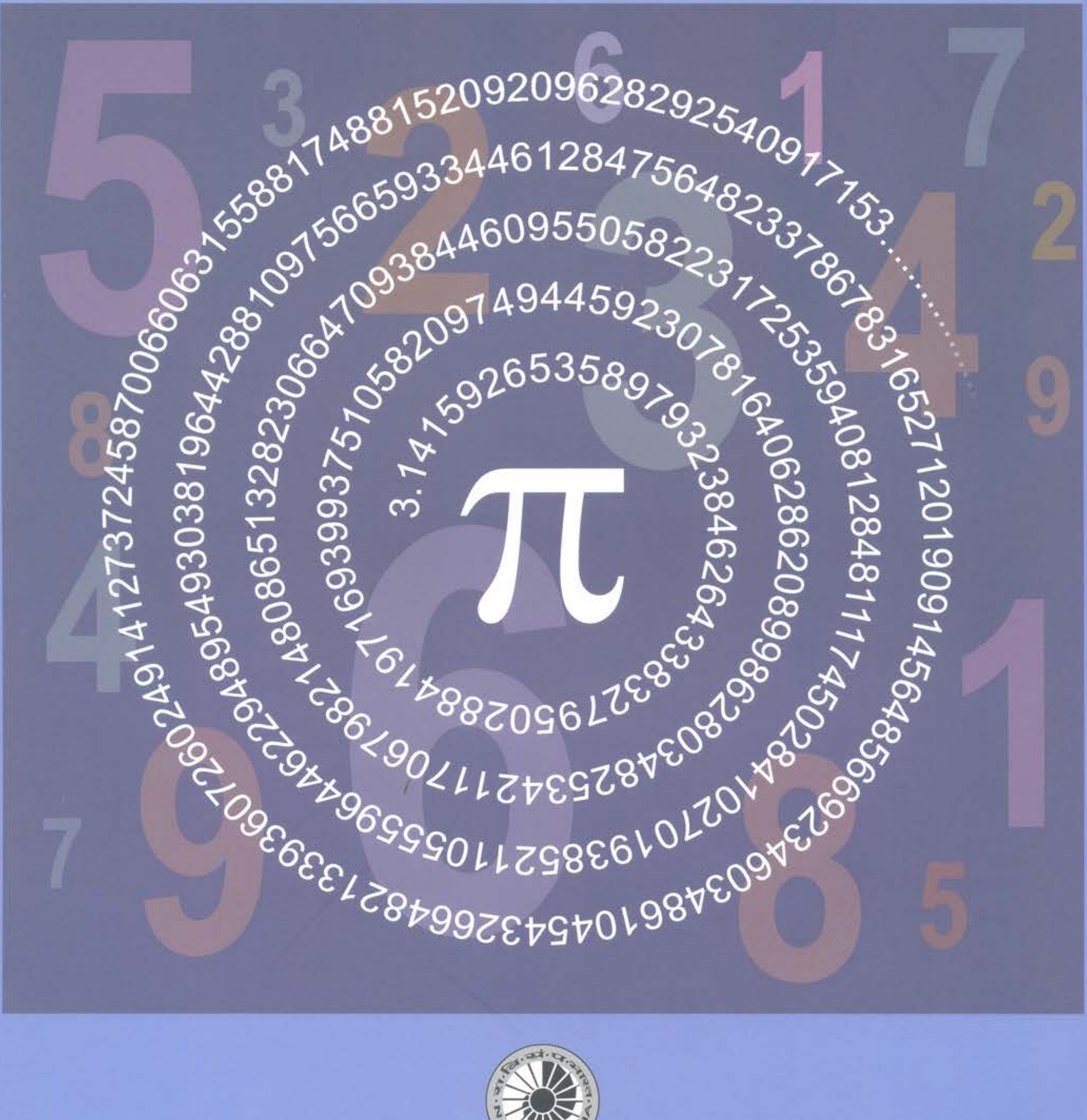

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Editorial

Penning an editorial for a belated issue is always a difficult task. The best I can possibly do is to begin on an apologetic note, and to say that the delay in bringing out this issue is sincerely regretted.

There are six articles in it contributed by professional science communicators, science historians and popular science writers.

The article 'Rise of Totalitarianism, Migration of Scientists and Creation of Atomic Bomb' traces the history of the emergence of totalitarian regimes in Europe after the First World War and subsequent migration of civilian scientists to other countries, which enriched the wartime R&D in countries like USA and UK leading to the creation of the atom bomb.

The article 'Science Museums: Improving Science Education' discusses proven methods for science museums working with teachers and their classes in the United States and India. Individual experiences of the authors from USA and India in teacher training for bettering formal science teaching in school education set-up in their respective countries enrich the content of the article.

'Rev. Felix Carey: Medical Missionary and Linguist' gives a brief historical account of the multi-faceted and gifted personality that he was and also of his contribution to the Indian society.

The article 'Waterpower Technology in India: Traditional Knowledge' traces the history and traditional practices in India in the area of development and management of water resources.

'NANOLAB: The Role for Science Centers in Capacity Building' is an article based on the authors' experiences in the development and running of the Nanotechnology laboratory in Science City Kolkata and speaks about how this facility is being used for exposing the students and the general public to this cutting-age technology as well as in developing a reasonable expertise among them in handling the technology for investigative purposes.

The last article of this issue 'Historiography of Plant Taxonomy in India' provides a historical account of plant taxonomy as it existed in India from ancient to the modern times.

We hope our readers will find the articles in this issue interesting and useful, and we look forward their feedback and constructive suggestions.

E Islam
Chief Editor

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VOLUME 3, NO. 2, JULY, 2012

Rise of Fascist and Nazi Totalitarianism, Migration of Scientists and Creation of Atomic Bomb

Jayanta Sthanapati

1. Introduction

The end of First World War in 1918 was also the end of autocratic German, Russian, Ottoman and Austria-Hungarian empires. The response to the rise of communism was the emergence of radical right wing politics, which went far beyond traditional conservative policies of even the Bismarckian type. In Italy first, and then in Germany, extreme nationalist parties took power and imposed dictatorships. Though there were differences between the Italian and the German cases, for our purpose it is enough to note the basic similarities.

Due to imposition to various discriminatory laws by these countries, innocent civilian scientists had to migrate to other countries in the years 1918-1943. Their whole hearted participation in wartime research and development immensely benefited two Allied powers, the United States and Great Britain. Some of the emigrated physicists contributed greatly in creating the atomic bomb that affected the Second World War decisively.

2. Totalitarianism in Europe (1918-1945)

Totalitarianism is a form of government in which the political authority exercises absolute and centralized control over all aspects of life, the individual is subordinated to the state and opposing political and cultural expression is suppressed. Two types of totalitarianism evolved: the right-wing totalitarianism, as in Germany and Italy, and the left-wing totalitarianism, as adopted in the Soviet Union. The right-wing totalitarianism had emerged in advanced societies and were supported primarily by middle class citizen, who preferred to maintain social and economic status quo even in the changed situation. Private ownership of industrial wealth was supported in such regime. These states had only one party led by a charismatic cult figure, like Adolf Hitler (1889-1945) in Germany and Benito Mussolini (1883-1945) in Italy. The Soviet case will not be discussed here for two reasons. First, Soviet scientists played little role in development of the atomic bomb during the second World War. Second, much work has been done to question, whether the category 'totalitarianism' can be applied simultaneously to the USSR and Nazi Germany [1]. The early development fascism in Italy and nazism in Germany, the similarities, the differences and the relationship between the two regimes has been studied by Alexander J. De Grand [2].

2.1 Fascism in Italy

Fascist leader Benito Mussolini was the Prime Minister of Italy from 30 October 1922 to 25 July 1945. The National Fascist Party (Partito Nazionale Fascista, PNF) was founded by Mussolini in Rome on 9 November, 1921. The name fascism was derived from a Latin word 'fasces', a Roman symbol of authority consisting of a bundle of rods and an ax. Italian fascism, an authoritarian political movement emphasized nationalism, anti-socialism, elitism, productivism and need for a strong leader. Fascist-type radical rigtht wing movements subsequently developed in a number of countries [3].

In June 1940, Mussolini led Italy into WW II, as a member of the Axis powers. The National Fascist Party was dissolved after Mussolini's capture during an Allied invasion of Italy on 24 July 1943. He was, however, rescued from prison by the German force on 12 September 1943 and Mussolini revived his party as the Republican Fascist Party (Partito Fascista Repubblicano, PFR) on 13 September 1943. Mussolini was executed by Italian partisans, pro-Allied Italians, on 28 April 1945, and the PFR was dissolved [4].

2.2 Nazism in Germany

Adolf Hitler (1889-1945) was the Chancellor of Germany from 30 January 1933 to 30 April 1945. He was the leader of "National Socialist German Workers' Party" or the Nazi Party from 1920 to 1945.

The 'German Workers' Party' was founded in Munich by Anton Drexler on 5 January 1919 with some forty members. Their political thinking was to build a strong nationalist, pro-military, anti-semitic party made up of working class people. Adolf Hitler, a Corporal in the German Army came in contact with the party on 12

September 1919. He then became a member and took charge of the party's propaganda. On 24 February 1920, in a meeting held in Munich, attended by some two thousand people, Hitler presented the out line of the 'Twenty Five Point' program of the German Workers' Party – which included: the union of all Germans in a Greater German Reich; rejection of treaty of Versailles; the demand for additional territories for the German people; citizenship determined by race with no Jew to be considered a German; all income not earned by work to be confiscated; a thorough reconstruction of the national education system; religious freedom except for religions which endanger the German race; and a strong central government for the execution of effective legislation. By the end of 1920, the the party was renamed as "National Socialist German Workers' Party" (National Sozialistische Deutsche Arbeiterpartei), it had a new symbol and about three thousand members [5].

3. Anti-Jewish Laws in European Countries (1933-1945)

The origins of the epidemic rise of antisemitism and its mass influence in European societies, before and during the Second World War, has been studied by eminent historians [6,7]. According to William Brustein, the four principal roots of antisemitism were racial, religious, economic, and political [8]. We will discuss the anti-Jewish laws enacted in select European countries from where scientists emigrated had to the United States and Great Britain and subsequently contributed for creation of the atomic bomb [9,10].

3.1. Germany

During the Nazi rule in Germany, three major sets of anti-Jewish legislation were enacted. The first of these laws was the 'Law for the Restoration of the Professional Civil Service' of 7 April 1933, which excluded selected civil servants from their jobs. The second set of legislations termed the 'Nuremberg Laws' came into force in September 1935. The Jews were stripped of their citizenship and lost their right to vote. The Jews were also prohibited to marry the Germans. The third set of laws introduced between 1936 and 1937, restricted Jewish participation in German economy. The government could confiscate Jewish property, through 'Aryanization', a process of dismissing Jewish employees and managers of a company. From September 1941, wearing a Jewish badge was made compulsory for the Jews when they went out in public.

In January 1933 Jewish population in Germany was about 5,23,000. Migration of Jews began immediately after the Nazis came to power. By September 1939, some 2,82,000 Jews had emigrated from Germany to the United States, Great Britain, Canada and some European and South American countries. Even during the first two years of World War II, emigration of Jews from Germany continued. In October 1941, Nazi government banned further emigration of Jews. The Jewish population in Germany was about 1,63,000 then. Large number of the Jews were murdered in Germany during the war [11].

3.2. Austria

On 12 March 1938, Austria was annexed into Nazi Germany. Austria remained as a German state until April 1945. At the time of annexation, Jewish population in Austria was about 1,82,000 and a major part of the Jewish community lived in Vienna. Anti-Jewish policies were introduced very soon restricting participation of the Jews in cultural, educational and social activities. Like the common men, thousands of notable persons were sent to concentration camps. Hundreds of factories and stores own by the Jews were shut down. From October 1941, Jews were not allowed to exit the boundaries of Austria. However, Jews in large number had emigrated to other countries, particularly to Great Britain and the United States by that time. During the Nazi occupation about 65,000 Jews were murdered [12].

3.3. Hungary

Hungary was a member of the Axis powers during World War II. Between 1938 and 1941, three anti-Jews laws were enacted in Hungary. The first law (29 May 1938) restricted employment of physicians, engineers and lawyers. The second law (5 May 1939) defined the Jews racially and restricted their employment in government. The third law (8 August 1941) prohibited marriage between Jews and non-Jews [13].

3.4. Italy

Fascist Italy enacted a set of laws on 18 November 1938, known as 'The Manifesto of Race'. It regarded true Italians to be descendants of the Aryan race. The Jews were seen as inferior and were banned from many professions, such as in governments, education, banking, etc. under the racial law [14].

3.5. Denmark

Nazi Germany occupied Denmark on 9 April 1940 with 'Operation Weserübung'. The country remained under German occupation till the end of World War II, when the Germans surrendered to Allied force on 5 May 1945. During the first three years Germans took a benign approach to Denmark and the Danish institutions could function normally. The Jewish population, which was about 0.2% of Denmark's total population, also lived unperturbed. However, on 28 September 1943, a German order was issued to deport Danish Jews [15].

3.6. France

In the 'Battle of France' Germany invaded France on 10 May 1940 and Italy declared war on France on 10 June 1940. Paris, the French capital was occupied by Axis powers on 14 June 1940. An Axis Collaborator State known as 'French State' was formed with Marshal Philippe Pétain as its head. The new government survived from 10 July 1940 to 25 August 1944. The government passed an anti-Jewish legislation, the 'Statute on Jews', on 3 October 1940 to group the Jews as an inferior community and to deprive them from the rights of French citizens. Within a year the Jews were excluded from army and education institutions, from the profession of doctors and lawyers, from government positions, from the jobs in industry and from many more civil rights [16].

3.7. The Netherlands

In 1939, when World War II broke out, the Netherlands decided to remain neutral. But the country was invaded by the Germans on 10 May 1940 and was liberated by the Allied Forces on 5 May 1945. During this period, the Germans deported the majority of the Jews to concentration camps. It is estimated that out of about 1,50,000 Jews who lived in the Netherlands in 1940, only about 30,000 survived the world war [17].

4. Forced Human Migration

Human migration has been classified as 'voluntary' and 'involuntary' based on the choice exercised by the migrants in leaving their homes [18]. Migration has also been divided into classes of 'impelled' migration, when the migrants retain some power to decide whether or not to leave, and 'forced' migration, when they do not have this power [19]. This bipolar view of population movement was however found to be too simplistic. It has been argued that migration generally happens under some kind of compulsion. Only a few migrations are wholly voluntary or wholly involuntary [20].

Forced migrations occur because of various factors such as, war and political conflict, persecution, ethnic discrimination, natural disasters, environmental degradation, etc. [21,22] Forced migration is categorized as refugees, internally displaced persons, and forcibly ousted people [23].

Refugees, as defined by the United Nations High Commissioner for Refugees, are persons who, "owing to well-founded fear of being persecuted for reasons of race, religion, nationality, membership of a particular social group or political opinion, [are] outside the country of [their] nationality and [are] unable or, owing to such fear, [are] unwilling to avail [themselves] of the protection of that country…" [24].

Internally displaced persons, according to the United Nations Commission on Human Rights, are those "persons or groups of persons who have been forced or obliged to flee or to leave their homes or places of habitual residence, in particular as a result of or in order to avoid the effects of armed conflict, situations of generalized violence, violations of human rights or natural or human-made disasters, and who have not crossed an internationally recognized State border" [25]. People are also forcibly ousted from their habitat through government intervention for implementation of developmental projects [26,27,28].

4.1. Migration of Scientists from Totalitarian States

Germany became a world leader in science by the end of the nineteenth century. The first Nobel Prize in Physics was awarded to German physicist Wilhelm Conrad Rontgen in 1901. The first Nobel prize in Physiology or Medicine was also won by a German scientist Emil Adolf Von Behring. Dutch physicist and organic chemist Jacobus Henricus Van't Hoff, was a professor of the University of Berlin when he received the first Nobel prize for Chemistry in 1901. Out of a total 100 Nobel prizes in science awarded during 1901-1932, until a year before the Nazis came to power, 33 went to Germany, 18 to Great Britain and 6 were earned by the United States. Such dominance of the Germans in science diminished slowly between 1933 and 1939 and very fast during and after the World War II. Table 3.1 presents world-wide distribution of Nobel prize winners in Physics, Chemistry, and Physiology or Medicine during 1901-1939 and also in the next 39 years, during 1943-1981. It clearly transpires that while Great Britain improved its strength (from 23 to 38) of Nobel laureates in science after World War II, Germany lost its pride (from 36 to 13), while the United States became the new world leader (from 14 to 117) [29].

Table 3.1 Number of Nobel Laureates in Science in some select Countries

Countries of the Nobel prize Winners (according to citizenship at the time award was made)	No. of Nobel Prize Winners in Science					
	Physics		Chemistry		Physiology or Medicine	
	Period		Period		Period	
	1901-1939	1943-1981	1901-1939	1943-1981	1901-1939	1943-1981
Austria	2	1	1	-	2	2
Denmark	1	2	-	-	3	1
France	6	2	6	-	4	4
Germany	**11**	3	**16**	8	**9**	2
Italy	2	-	-	1	1	1
Japan	-	3	-	1	-	-
Netherlands	4	1	2	-	2	-
Russia	-	7	-	1	2	-
Sweden	2	2	3	1	1	4
Switzerland	1	-	3	1	1	4
Great Britain	10	10	6	**16**	7	**12**
United States	6	**41**	3	**22**	5	**54**

Nazi Germany and its occupied nations, and fascist Italy experienced large scale emigration of scientists in very different time spans between 1918 and 1943. Most of the emigrants, however, moved to Great Britain and the United States for refuge [30].

A list of thirty five Nobel laureates in science who emigrated to Great Britain and the United States from the totalitarian regime during 1930-1945 is presented in Table 3.2.

Table 3.2 Nobel Laureate Scientists who Migrated from Austria, Denmark, France, Germany and Italy between 1930 and 1945

Name	Born-Died	Jew	Nobel prize			Migration		
		Yes/No	Year	Subject	Country	Year	From	To
Bethe, Hans A.	1906-2005	Yes (Mother)	1967	Physics	USA	1933 1935	Germany England	England USA
Bloch, Felix	1905-1983	Yes	1952	Physics	USA	1933	Germany	USA
Block, Konard Emil	1912-2000	No	1964	Physiology or Medicine	USA	1934	Germany	Switzerland
Bohr, Niels	1885-1962	Yes (Mother)	1922	Physics	Denmark	1943	Denmark	USA (via England)
Born, Max	1882-1970	Yes	1954	Physics	UK	1933	Germany	England
Chain, Ernst Boris	1906-1979	Yes	1945	Physiology or medicine	UK	1933	Germany	England
Cournand, Andre Frederic	1895-1988	No	1956	Physiology or medicine	USA	1930	France	USA
Dam, Carl Peter Henrik	1895-1976	No	1943	Physiology or Medicine	Denmark	1941	Denmark	USA
Debye, Peter	1884-1966	No	1936	Chemistry	Germany	1940	Germany	USA
Einstein, Albert	1879-1955	Yes	1921	Physics	Germany	1933	Germany	USA
Fermi, Enrico	1901-1954	Yes	1938	Physics	Italy	1938	Italy	USA
Franck, James	1882-1964	Yes	1925	Physics	Germany	1933	Germany	USA
Gabor, Dennis	1900-1979	Yes	1971	Physics	UK	1933	Germany	England
Goeppert-Mayer, Maria	1906-1972	No	1963	Physics	USA	1930	Germany	USA
Haber, Fritz	1868-1934	Yes	1918	Chemistry	Germany	1934	Germany	England
Hess, Victor Francis	1883-1964	Yes	1936	Physics	Austria	1938	Austria	USA
Katz, Bernard	1911-2003	Yes	1970	Physiology or Medicine	UK	1934	Germany	England
Krebs, Hans Adolf	1900-1981	Yes	1953	Physiology or Medicine	UK	1933	Germany	England
Lippmann, Fritz Albert	1899-1986	Yes	1953	Physiology or Medicine	USDA	1939	Germany	USA (via Denmark)
Loewi, Otto	1873-1961	Yes	1936	Physiology or Medicine	Austria	1940	Austria	USA
Luria, Salvador Edward	1912-1991	Yes	1969	Physiology or Medicine	USA	1938 1940	Italy France	France USA
Meyerhof, Otto Fritz	1884-1951	Yes	1922	Physiology or Medicine	Germany	1938 1940	Germany France	France USA
Pauli, Wolfgang Ernst	1900-1958	Yes	1945	Physics	USA	1940	Austria	USA
Penzias, Arno Allan	1933-	Yes	1978	Physics	USA	1940	Germany	USA
Perrin, Jean Baptiste	1870-1942	No	1926	Physics	France	1940	France	USA
Petrutz, max Ferdinaud	1914-2002	Yes	1962	Chemistry	UK	1936	Austria	England
Polanyi, John Charles	1929-	Yes	1986	Chemistry	Canada	1933	Germany	England
Herzberg, Gerhard	1904-1999	Yes (wife)	1971	Chemistry	Canada	1935	Germany	Canada
Hevsey, George de	1885-1966	Yes	1943	Chemistry	Hungary	1943	Denmark	Sweden
Schrodinger, Erwin	1887-1961	No	1933	Physics	Germany	1933	Germany	England
Segre, Emilio Gino	1905-1989	Yes	1959	Physics	USA	1938	Italy	USA
Steinberger, Jack	1921-	Yes	1988	Physics	Switzerland	1934	Germany	USA
Stern, Otto	1888-1969	No	1943	Physics	USA	1933	Germany	USA
Wigner, Paul Eugene	1902-1995	Yes	1963	Physics	USA	1930	Germany	USA
Willstatter, Richard	1872-1942	Yes	1915	Chemistry	Germany	1939	Germany	Switzerland

4.1.1. Migration of Scientists from Germany

Reich Ministry for Education and Science in 1934 prepared a list of 614 university teachers who would be dismissed from their positions. Most of them (571) were subsequently dismissed on various grounds – 384 being non-Aryans, 80 for political reasons and a large number of 107 for simplification of administration [31]. By the end of 1935, nearly 1700 scholars in all fields were dismissed from German posts, which included over 100 physicist, about 25% of total number of physicists employed in Germany [32].

The sentiment against the anti-semitic movement in Germany was very strong in Great Britain and the United States. In 1933, the British 'Academic Assistance Council' (later renamed the 'Society for Protection of Science and Learning') was founded to place refugee scientists in appropriate research or teaching positions. In the same year the 'Emergency Committee in Aid of Displaced German (later changed to Foreign) Scholars' was set up in the United States with similar objectives. The Presidents of seventeen American Colleges and Universities were the members of the committee [33]. The situation, however, changed after Germany annexed Austria in March 1938. Both United States and the British governments were no longer very keen to let the Jews in [34].

4.1.2. Migration of Scientists from Italy

Benito Mussolini was keen to promote scientific research in Italy, but due to implementation of the Italian racial law, the 'Manifesto in the Defense of the Race' many renowned scientists emigrated. Italian scientists, much smaller in number compared to migrated scientists from Germany, left the country during 1938-1939. Enrico Fermi (1901-1954), Emilio Segre (1905-1989) and Bruno Rossi (1905-1993), were some of them who emigrated to the U.S. Fermi was awarded the 1938 Nobel Prize in Physics and Segre received the Physics Nobel Prize in 1959. Both of them emigrated to the U.S. in 1938 and made significant contribution for the Manhattan Project. Rossi had migrated to the United States in 1939. During the World War II, he first worked at the Radiation Laboratory of the MIT as a consultant for radar development and then for the Manhattan Project from 1943 to 1945 [35].

5. Role of Emigrated Physicists in Creating the Atomic Bomb

5.1. The Manhattan Project

The Manhattan Project, a secret military project to produce nuclear weapon was initiated in June 1942. It was originally based in Manhattan, New York, as a small research program. Three major research and production sites in the US were at the Oak Ridge Laboratories in Tennessee for production of enriched U-235; at Hanford, in eastern Washington state for production of weapons-grade plutonium; and at Los Alamos Laboratory, New Mexico for research, design and assembling of nuclear weapons.

From 1942 to 1946, the project was under the command of Brigadier-General Leslie R. Grooves Jr. (1896-1970) of US Army Corps of Engineers. Immediately after his appointment in September 1942, Groves appointed Robert J. Oppenheimer (1904-1967) an American physicist, as the Scientific Director of the Manhattan Project.

The project eventually employed more than 1,30,000 people at more than 30 research and production sites across the United States, the United Kingdom and Canada with a budget of nearly two million US dollars [36].

5.2 Physicists of the Manhattan Project

An excellent account of the Manhattan Project based on personal interviews of atomic scientists was written by Robert Jungk in 1956. The title of the book "Brighter than a Thousand Suns: A Personal History of the Atomic Scientists" is based on the verse from the Bhagavad Gita: "If the radience of a thousand suns were to burst into the sky, that would be the splendor of the Mighty One." [37].

The Manhattan Project had involved twenty three Nobel laureate physicists, who either received the prize before joining the project or won the prize later during their illustrious scientific career. Nine of them had emigrated from different European countries. Table 3.3 depicts a select list of first rate emigrated physicists who made significant contribution to the project [38].

Table 3.3 A select list of Emigrated Physicists of the Manhattan Project

Name of Physicists	Emigrated in	Country of Birth	Jew (Yes/No)	Position in Manhattan Project	Primary Location
Bethe, Hans *	1933	Germany	Yes	Chief , Theoretical Division	Los Alamos, New Mexico (NM)
Bloch, Felix *	1933	Switzerland	Yes	Uranium Isotopes Project	Los Alamos, NM
Bohr, Neils *	1943	Denmark	Yes	Consultant to the project	Los Alamos, NM
Breit, Gregory	1915	Russia	Yes	Fast neutron Project	Univ. of Chicago Metallurgical Laboratory
Einstein, Albert *	1933	Germany	Yes	Consultant to the project	Los Alamos, NM
Fermi, Enrico *	1938	Italy	Yes	Group leader-Theoretical	Los Alamos, NM
Franck, James *	1933	Germany	Yes	Director, Chemistry Group	Univ. of Chicago Metallurgical Laboratory
Frisch, Otto Robert	1933	Austria	Yes	Critical Assembly Group	Los Alamos, NM
Goeppert-Mayer, Maria *	1930	Germany	No	Separation of Isotopes of uranium	S.A.M. Lab, Columbia University
Goudsmit, Samuel	1927	The Netherlands	Yes	Scientific Head, Alsos Mission	Europe
Kurti, Nicholas	1933	Hungary	Yes	Separation of Isotope	England
Neumann, John Von	1930	Hungary	Yes	Theoretical Division	Los Alamos, NM
Peierls, Rudolf	1933	Germany	Yes	British Mission	Los Alamos, NM
Segre, Emilio *	1938	Italy	Yes	Group Leader, Radioactivity	Los Atamos, NM
Simon, Francis	1933	Germany	Jew	Separation of Isotope	England
Szilard, Leo	1933	Hungary	Yes	Group Leader – Met. Lab.	Univ. of Chicago Met. Lab.
Teller, Edward	1933	Hungary	Yes	Thermonuclear Research	Los Alamos, NM.
Ulam, Stanislaw	1935	Austria	Yes	Hydrodynamics of Implosion	Los Alamos, NM
Weisskopf, victor	1937	Austria	Yes	Theoretical Division	Los Alamos, NM
Wigner, Eugene *	1930	Hungary	Yes	Group leader, Metallurgical Laboratory	Univ. of Chicago Metallurgical Laboratory

* Nobel laureate in Physics

5.3.1 Hans Albrecht Bethe (1906-2005) was awarded the 1967 Nobel prize in Physics for his contributions to the theory of nuclear reactions, especially his discoveries concerning the energy production in stars. He was born in Strasbourg in Germany in a family with Jewish mother and Christian father. Bethe earned PhD in physics under supervision of Arnold Sommerfeld in 1928 from the University of Munich. During 1930-1931, he was a Rockefeller Research Fellow at University of Cambridge and University of Rome. In Rome, he worked with Enrico Fermi. Bethe emigrated from Nazi Germany in 1933 and joined in University of Manchester in England as a lecturer. In 1935 he moved to USA and started his career as an Assistant Professor of Physics at Cornell University in Ithaca, New York. He became a naturalized citizen of the United States in 1941. Bethe headed the theoretical physics division of the Manhattan Project at the Los Alamos Laboratory during 1942-1944 [39].

5.3.2 Felix Bloch (1905-1983), a Swiss-born American Physicist was awarded the 1952 Nobel prize in Physics, jointly with Edward Mills Purcell for their development of new methods for nuclear magnetic precision measurements and discoveries in connection therewith. He was born in a Jewish family in Zurich. Bloch received PhD in physics under the supervision of Werner Heisenberg from the University of Leipzig in 1928. He served at that University during 1932-1933, as a Privatdozent or Lecturer. The rise of the Nazi compelled him to leave Germany in 1933. After working with Enrico Fermi for a year at the University of Rome as a Rockefeller Foundation Fellow, he moved to USA and joined at Stanford University, California as an Acting Associate professor of Physics in 1934. He became a naturalized American citizen in 1939. For a brief period during World War II, Bloch worked at Los Alamos National Laboratory for the Manhattan project [40].

5.3.3 Niels Henrik David Bohr (1885-1962) was a Danish physicist who received Nobel prize in physics in 1922 for his services in the investigation of the structure of atoms and of the radiation emanating from them. He was born in Copenhagen. Bohr received doctorate in physics from Copenhagen University in 1911. He served as a lecturer of physics at the Copenhagen University from 1913 to 1914, and then at Victoria University of Manchester from 1914 to 1916. Bohr returned to Copenhagen in 1916 to become a professor of physics at the University. In 1921, he established 'Institute of Theoretical Physics" at Copenhagen University and became its Director. On 31st August 1939, Niels Bohr and John A. Wheeler (1911-2008) published a theoretical analysis of nuclear fission and predicted that uranium-235 is more fissile than uranium-238 and that the undiscovered element 94-239 (later known as plutonium-239) would be very fissile.

When the Germans invaded and occupied Denmark in 1940, Bohr did not leave Denmark immediately, although his mother came from a Jewish family. However, in 1943, a Nazi order was passed to arrest Jews in Copenhagen. As a result, Bohr escaped to Sweden and subsequently reached England. There he came to know about the top secret Manhattan Project, and was deputed by the British authorities to Los Alamos Laboratory in New Mexico. Bohr worked for the project for about two years and returned to 'Institute of Theoretical Physics' at Copenhagen University after the World War II [41].

5.3.4 Gregory Breit (1899-1981) was born in a Jewish family in Mykolaiv, Russia and had emigrated to the United States in 1915. During next six years he got AB, AM and PhD physics degrees from Johns Hopkins University in Baltimore. In 1942, he worked for the Manhattan project at Chicago Metallurgical Laboratory as a coordinator of Fast-Neutron project [42].

5.3.5 Albert Einstein (1879-1955) was born in a Jewish family at Ulm in German Empire. He was awarded the 1921 Nobel prize in Physics for his services to Theoretical Physics, and especially for his discovery of the law of the photoelectric effect. From 1914 to 1932 he was a professor of theoretical physics at the University of Berlin. With the rise of the Nazis in Germany, he emigrated to the United States in 1933 and joined the Institute for Advanced Study in Princeton. In December 1938, German chemists Otto Hahn and Fritz Strassman detected the element barium after bombarding uranium with neutrons. The result was interpreted as being nuclear fission by Austrian physicists Lise Meitner and Otto Robert Frisch. Frisch confirmed this experimentally on 13 January 1939. On 2 August 1939, Albert Einstein wrote a letter to the US President Franklin D. Roosevelt (1882-1945), wherein he suggested that the United States should initiate research for development of atomic bomb in a big way, as it would have vast destructive power. It is believed that the letter was largely written by Leo Szilard in consultation with fellow Hungarian physicists Edward Teller and Eugene Wigner. The letter, however, was brought to the notice of President Roosevelt on 11 October 1939. That was the beginning of the organized wartime research to develop the atomic bomb by the Allied powers. Einstein became an American citizen in 1940 [43].

5.3.6 Enrico Fermi (1901-1954) was an Italian-born American physicist who received the 1938 Nobel Prize in Physics for his demonstrations of the existence of new radioactive elements produced by neutron irradiation, and for his related discovery of nuclear reactions brought about by slow neutrons. He was born in Rome. Fermi received PhD in physics in 1922 from University of Pisa. Between 1922 and 1926, he served at the Universities of Gottingen, Rome, Leiden and Florence for brief periods, in various capacities. He was a Professor of Theoretical Physics at the University of Rome from 1926 to 1938. In May 1934, Fermi irradiated uranium with neutrons and produced the first transuranic element, and also achieved unknowingly, the world's first nuclear fission. When Anti-semitic legislation was introduced in Italy in November 1938, Fermi emigrated from Italy to the United States with his wife Laura, a Jewish lady, and his two children. He was appointed a professor of Physics at Columbia University, New York in 1939. On 25 January 1939, a team of physicists and chemists led by him at Columbia experimentally verified the European discovery of nuclear fission of uranium via neutron bombardment. On 2 December 1942, Fermi and his team at the University of Chicago produced world's first controlled and self-sustained fission reaction. He played a very significant role in Manhattan Project, as a Leader of Physics Group (1942-1943) and Director of Argonne Branch (1943-1944), both at the Chicago Metallurgical Laboratory, and thereafter as Associate Director of Los Alamos Laboratory. Fermi became an American Citizen in 1944 [44].

5.3.7 James Franck (1882-1964) was a German physicist who received Nobel prize for Physics in 1925 jointly with Gustav Ludwig Hertz for their discovery of the laws governing the impact of an electron upon an atom. Franck was born in a Jewish family in Hamburg. He received PhD in physics under Emil G. Warburg from the University of Berlin in 1906. He taught at University of Berlin during 1906-1918 and became Head of Physics Division of Kaiser Wilhelm Institute for Physical Chemistry, Berlin-Dahlem in 1918. Frank was Professor and Director of Institute for Experimental Physics II of University of Gottingen from 1920 until 1933. He resigned from the University of Gottingen in 1933 as a personal protest against the racial laws introduced by the Nazis in Germany. He then moved to USA and joined at Johns Hopkins University, Baltimore as a Professor. During World War II he worked for the Manhattan project at Chicago Metallurgy Laboratory as Director of Chemistry Division (1942-1943), as Associate Director (1943-1944) and finally as a Consultant (1944-1945) [45].

5.3.8 Otto Robert Frisch (1904-1979) was an Austrian-British physicists. He was born in a Jewish family in Vienna. After receiving PhD in physics from the University of Vienna in 1926, he worked under Otto Stern as a research scholar until 1933. When Nazis rose to power Irish left Germany and joined Brikbeck College of University in London. During 1934-1938, he worked under Neils Bohr at Institute of Theoretical Physics of the University of Copenhagen. He returned to England in 1939 and worked with Rudlf Peierls at the University of Birmingham. They produced the important Frisch-Peierls memorandum on 'critical mass calculations' for an atomic bomb. He moved to the United States in 1943 and worked for the Critical Assembly Group of Manhattan Project till 1945 [46].

5.3.9 Maria Goeppert-Mayer (1906-1972) was a German-born American physicist, who received one half of Nobel Prize in Physics in 1963, jointly with J. Hans D. Jensen for discoveries concerning nuclear shell structure. She was born at Kallowitz, in the German Empire. Maria received PhD in physics under supervision of Max Born from the University of Gottingen in 1930. She moved to the United States with her husband Joseph Edward Mayer, an American Rockefeller Fellow and became an Assistant at Johns Hopkins University, in Baltimore. She worked there in various positions until 1939. She moved to Columbia University, New York in 1942 and worked until 1945 with Harold Urey at the S.A.M. Laboratory on separation of isotopes of Uranium, as an activity of the

Manhattan Project. She also worked for the atomic bomb project at Los Alamos Laboratory, as a Researcher for some time [47].

5.3.10 Samuel Abraham Goudsmit (1902-1978) was a Dutch-American physicist. He received PhD in physics from University of Lieden in 1927 and then moved to the United States and served at the University of Michigan between 1927 and 1946. During World War II he researched at MIT Radiation Laboratory and served as the head of Alsos Mission of the Manhattan Project to assess the German ability to build an atomic bomb [48].

5.3.11 Nicholas Kurti (1908-1998) was a Hungarian-British physicist. He was born in a Jewish family in Budapest. Kurti received M.S. degree from the University of Paris-Sorbonne in 1929 and Ph.D. in physics from the University of Berlin in 1931. He then taught physics there until 1933. When Hitler rose to power, Kurti moved to England and joined the Clarendon Laboratory of the University of Oxford. During World War II, he worked for the Manhattan Project in England [49].

5.3.12 John Von Neumann (1903-1957) was born in a Jewish family in Budapest. He was baptized a Roman Catholic in 1930. Von Neumann received PhD in mathematics from University of Budapest in 1926 and was a lecturer at University of Berlin from 1927 to 1930. He then moved to the United States as a visiting Professor of Mathematical Physics at Princeton University. He was appointed a professor of Institute for Advanced Study, Princeton in 1933, which academic post he held till 1957. He was also a consultant of the Los Alamos National Laboratory from 1943 to 1955. Along with Edward Teller and Stanislaw Ulam, he worked out key steps involved in thermonuclear reactions in connection with development of hydrogen bomb [50].

5.3.13 Rudolf Ernst Peierls (1907-1995) was a German-born British physicist who had a major role in Britain's nuclear programme. He also made significant contribution in the Manhattan project. Peierls was born in a Jewish family in Berlin. He received PhD in physics from the University of Leipzig in 1929. When Hitler came to power in Germany, Peierls was a Rockefeller research scholar at Cambridge University in England. He was a professor of Physics at university of Birmingham from 1937 to 1963. He worked on an atomic research project with Otto Robert Frisch and James Chadwick. In 1940 he authored a paper with Frisch that showed how one could construct an atomic bomb from a small amount of fissionable Uranium-235. In 1943 he moved to United States and worked for the Manhattan project until 1945 [51].

5.3.14 Emilio Gino Segre (1905-1989) was an Italian-born American physicist and Nobel laureate in Physics. He received the prize in 1959 jointly with Owen Chamberlain for their discovery of anti-proton. Segre was born in a Jewish family in Tivoli. He earned PhD in physics under supervision of Enrico Fermi from the University of Rome in 1928. Thereafter, as a Rockefeller Foundation Fellow, he worked with Otto Stren in Hamburg and with Pieter Zeeman in Amsterdam. He was an Assistant Professor of physics at the University of Rome from 1932 to 1935, and there he worked with Enrico Fermi. In 1936, he was appointed as a Professor of Physics at the University of Palermo in Italy. In 1938, antisemitic laws imposed in Italy, barred Jews from holding university positions. At that time, he was a visiting scientist at E.O. Lawrence's Radiation Laboratory at the University of California in Berkeley. Segre did not return to Italy and stayed in the United States, where he became a naturalized citizen in 1944. At the University of California, Berkeley, he held various positions like Research Associate of Radiation Laboratory (1938-1946), professor of Physics (1946-1972) and Emeritus Professor of Physics (1972-1989). During 1943-1946, he was a leader of the Radioactivity Group at Los Alamos Laboratory, New Mexico [52].

5.3.15 Francis Simon (1893-1956) was a German-British physical chemist and physicist. He was born in a Jewish family in Berlin. He received PhD in physics from the University of Berlin. He moved to England in 1933 and joined the Clarendon Laboratory in the University of Oxford. In 1940, he separated U-235 from U-238, an important step towards development of atomic bomb [53].

5.3.16 Leo Szilard (1898-1964) was born in a Jewish family in Budapest in Hungary. Under the supervision of Max von Laue, he received PhD in physics from the University of Berlin in 1922. When Hitler came to power in 1933, Szilard, a lecturer at the University of

Berlin, left Germany and joined at St. Bartholomew's Hospital in London as a researcher. While in England, In September 1933, Szilard conceived a process of nuclear chain reaction and thought that a nuclear bomb could be developed on the basis of energy-producing chain reaction. Between 1935 and 1937 he served at the Clarendon Laboratory of the University of Oxford as a research physicist. He then moved to the United States and joined at Columbia University, New York in 1938 and came in contact with Enrico Fermi. The duo discovered the neutron multiplication properties of uranium, which proved that a nuclear chain reaction and nuclear weapons were possible. In 1939, he inspired Albert Einstein to write a letter to President Roosevelt to consider development of atomic bomb as an American project. In 1942 Szilard moved to University of Chicago for the Manhattan Project. There he succeeded in producing sustained chain reaction. He became a naturalized citizen of the United States in 1943 [54].

5.3.17 Edward Teller (1908-2003) was born in a Jewish family in Budapest. He had to leave Hungary in 1926, primarily due to 'numerus clausus' rule which restricted the number of students who may study at the University. After graduating in chemical engineering at the University of Karlsruhe, Germany he received PhD under Werner Heisenberg in physics in 1930 from the University of Leipzig. He then became a Research Associated at the University of Gottingen. When Hitler came to power in 1933, Teller moved to Denmark and joined the Institute for Theoretical Physics at Copenhagen as a Rockefeller Fellow to work under Niels Bohr. In 1934, Teller moved to England to become a lecturer at London City College. In 1935, he moved to the United States and became a Professor of Physics at George Washington University. He took keen interest to use nuclear energy for 'fission' and 'fusion'. During 1941-1942, he worked as a researcher at Columbia University, New York. In 1942, he got involved in Manhattan Project and served as a researcher at Chicago Metallurgical Laboratory (1942-1943) and thereafter at Los Alamos Laboratory as Leader of Hydrodynamics of Implosion and Super Theory Group (1943-1944) and as Leader of General and Super Theory Group (1944-1946). In 1950, American President Harry S. Truman, following the news of first test detonation of Soviet atomic bomb, ordered an accelerated program for development of hydrogen bomb, a potentially much powerful weapon than the atomic bomb. Teller and Stanislaw Ulam came up with workable hydrogen bomb designs, while working at Los Alamos Laboratory in 1952 [55].

5.3.18 Stanislaw Ulam (1909-1984) was born in Lemberg, Austria-Hungary in a Polish Jewish family. He received a DSc degree in mathematics at Polytechnic Institute of Lvov in 1933. In 1935, He moved to the United States and joined the Institute for Advanced Study at Princeton. During 1936-1939 he spent academic years at Harvard University at Cambridge, but returned to Poland in summer. He permanently moved to the United States in 1939, only two weeks before the Germans invaded Poland. Ulam taught at University of Harvard (1939-1940) and then at University of Wisconsin, Madison (1940-1943). In 1943, he received a letter from Hans Bethe to work at Los Alamos Laboratory, for the Manhattan Project. Ulam served at Los Alamos from 1943 to 1957 as a researcher and made significant contribution for development of atomic bomb, as also for hydrogen bomb [56].

5.3.19 Victor Frederick Weisskopf (1908-2002) was born in a Jewish family in Vienna. He receive PhD in physics from University of Gottingen in 1931. During 1931-1932, he worked as Research Associate, first at the University of Leipzig under Werner Heisenberg and then at the University of Berlin under Erwin Schrodinger. Under a Rockefeller Foundation Fellowship, between 1932-1933, he further worked with Paul Dirac at the Cambridge University and then with Niels Bohr at the University of Copenhagen. In the fall of 1933 he became Research Assistant to Wolfgang Pauli at Eidgenossische Technische Hochschule in Zurich, Switzerland, where he remained for about two and a half years. In 1936 Weisskopf again moved to Copenhagen and worked as a Research Associate of Niels Bohr. With the increasing antisemitism in Germany, Weisskopf in 1937 decided to move to the United States with his wife. Neils Bohr arranged for an Physics Instructor's job for him at University of Rochester, New York. He subsequently became Assistant Professor of Physics and remained there until 1945. Weisskopf also worked for the Manhattan Project, at Los Alamos Laboratory in New Mexico from 1943 to 1946 as Deputy Leader of Theory Group [57].

5.3.20 Eugene Paul Wigner (1902-1995) was a Hungarian-born American theoretical physicist. In 1963 he received one half of the Nobel Prize in Physics for his contributions to the theory of the atomic nucleus and the elementary particles, particularly through the discovery and application of fundamental symmetry principles. He was born in a Jewish family in Budapest. In 1925 he received doctor of science degree from Technische Hochschule (Technical institute) in Berlin. He served in Germany until 1930 in various positions, as Research Assistant and Lecturer at University of Berlin and also as a Research Assistant at University of Gottingen. He was appointed a Research professor at Princeton University in 1931. Wigner was made a Leader of the Theoretical Group of the Manhattan project at Chicago Metallurgical Laboratory in 1942. He remained associated with the project until 1945 [58].

6. The End of World War II

By 1943, three different designs of nuclear bombs had evolved under the Manhattan Project – all of which involved nuclear fission as the basic mechanism. The proposed designs were for (i) a uranium-235 gun-type bomb, (ii) a plutonium-239 gun-type bomb, and (iii) a plutonium implosion-type bomb. The first atomic bomb of the world, an implosion-type plutonium device, code-named 'The Gadget' was detonated by the United States Army on 16th July 1945 at a desert in New Mexico. The exploded bomb produced energy equivalent to the explosion of about 20 kilotons of TNT. Only two atomic bombs have ever been used in war – both detonated by the United States over Japan near the end of World War II. 'Little Boy', a uranium-235 gun-type bomb was dropped on Hiroshima on 6th August 1945 by Boeing Super-fortress 'Enola Gay' aircraft of the US Army Air Force. 'Thin Man', a plutonium-239 gun-type weapon, was planned, but never produced due to technical inconvenience. 'Fat Man', a plutonium implosion-type bomb, similar to 'The Gadget' in design was detonated on Nagasaki on 9th August 1945 [59].

7. Conclusion

Rise of totalitarianism, during the period between the two World Wars, in Nazi Germany and Fascist Italy, under the leadership of intolerant and prejudiced dictators Adolf Hitler and Benito Mussolini, had resulted in forced migration of hundreds of first grade scientists to two democratic nations, Great Britain and the United States. Consequently, Germany lost its supremacy in science and technology. Italy too lost its first grade scientists. The Refugee scientists, particularly the physicists, then greatly contributed to the collaborative Anglo-American project to create the ultimate weapon, the atomic bomb, that ended the world war.

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Science Museums: Improving Science Education

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Across the world, it is acknowledged that quality science education is critical to building a dynamic workforce and a national population with the tools to evaluate and embrace progress. At the same time, there are not nearly enough teachers trained in science content, and even less who can teach these subjects using the most successful methods: hands-on and inquiry-based.

There are a lot of responses to these problems, and they all count. But together, they are not enough:

1) Formal university teacher accreditation programs are key, but their graduation rates are not large enough to yield large scale improvements in science teaching.

2) Informal science media, including television and web-sites like www.Thinkfinity.org for teachers and students, are valuable for their broad reach, but cannot replace formal education.

3) Likewise, content in periodicals such as Sanctuary-Asia kids science activities running in the comics sections of many Indian newspapers or shortcutscomic.com in U.S. newspapers are a powerful launchpad for interest in the natural sciences, but cannot replace classroom work.

More resources are needed to make real-time change in the quality of science education. And science museums are positioned to play key roles. Science museums are located throughout the nation in both rural and urban areas, and they have developed outreach programs beyond their buildings. They are full of science-educated staff and exhibits. And they have equipment appropriate to teaching about science and math. Many are experienced in working with school classes in their museums. Some also are experienced in working with classes in school settings. A few excel in training teachers.

In this article we will look at proven methods for science museums working with teachers and their classes in the United States and India.

In the United States we'll use the model of the New York Hall of Science where early work with teachers and students revealed several key issues:

1) More than 80% of elementary schools in New York City have teachers assigned to teach science without ever having taken a science course in college or received in-service (professional – post university) training.

2) These teachers and even some with science education backgrounds are uncomfortable teaching science subjects, communicate this discomfort to their students, and tend to teach by rote from science textbooks using the teacher answer sheet to determine correct outcomes.

3) When scientists/educators or science museum staff present science in the classroom or at the museum, both teachers and students rate the programs very highly…BUT the success of these "specialist science presenters" is seen by teachers and students as further proof that science is not something that they can really master. It is in the purview of specialists.

As a result, to reach the goal of increasing the quality of science education in New York City, the nation's largest school district, the Hall set these key objectives:

1) Every education program includes teacher professional development and empowerment – museum staff are tasked to teach, mentor and coach teachers. They do not replace them.

2) School administrators and educators are involved in program planning – museum staff seek to understand curriculum requirements, testing demands, limited facilities and equipment, schedule constraints, and special needs that school-based professionals understand deeply.

3) School administrators, educators and students are involved in evaluation.

4) Wherever possible, the school's own systems are integrated into museum programs: test preparation, school-day schedules, teacher professional development, union and school administration requirements and budgets.

Using Museum-owned Equipment to Train and Empower Teachers

STARLAB™ projector training for teachers in professional development at the New York Hall of Science. Frank Signorello, instructing. (Photo credit: New York Hall of Science)

The best science educators know the content appropriate to their grade level(s) and a diverse set of methods to ensure teaching across many learning styles and life experiences that students bring into the classroom. The best science educators are confident in their knowledge of content and methods, and that confidence is also projected to their students who see them as able to teach science well.

Because many teachers do not have the resources necessary to teach beyond textbooks, and because textbooks have a tendency to encourage rote learning, one of the first programs undertaken sought a model for providing teachers with content, methods and equipment for use in their classrooms. The model was the STARLAB™ training and rental program, Many Indian science museums also own portable planetariums with STARLAB™projectors.

Teachers engaged in 20-30 hours of training in astronomy, cosmology and traditional constellation mythsrelated to the New York State mandated science curricula across a number of grade levels. They also learned proven hands-on and inquiry based methods for working with STARLAB™ and developed their own lesson plans. At the end of their training they received a week's free STARLAB™ portable planetarium loan for use in their school building and they were certified to rent additional weeks of STARLAB™ in their school.

A typical STARLAB™ week led by a STARLAB™ certified science teacher included a science curriculum unit with their own class and others in the same grade, and a parent night where both the trained teacher and students led STARLAB™ presentations in astronomy, cosmology or mythology.

Training on STARLAB™ portable planetarium set-up. (Photo credit: New York Hall of Science)

Evaluation demonstrated that in both New York City and science museums replicating this model in rural areas, trained teachers taught effectively using STARLAB™, they increased the use of hands-on methods in other aspects of their teaching, their students and others in the school saw them as able science teachers, and parents who attended STARLAB™ nights had more positive attitudes toward science education in their schools and their own child's ability to learn science.

The science museum as a part of education infrastructure supplying well-maintained, specialized equipment, and content and methods training to teachers on a consistent and ongoing basis is a powerful vehicle for increasing the quality of science education. In addition, if equipment can be rented at a fee equal to the nominal cost of maintenance, shipping and replacement, the museum program can be self-sustaining.

This model has been replicated in New York with a Microbiology Program: video-microscope (for all class teaching), field microscopes, organisms and culturing supplies for hands-on teaching. Abiotechnology- and a forensic-science based information technology program using a computer-mediated teacher/student software interface has also been produced and evaluated.

Using Teacher Training and Classroom Lesson Modeling to Improve Science Education

Teachers learn content & methods at the New York Hall of Science. (Photo credit: New York Hall of Science)

Another effective model for increasing the quality of science teaching involves work at the museum and in the classroom. In New York we had two district practices upon which to base training:

1) Required Annual Professional Development Days: Students are released from school and teachers choose from a catalogue of training offerings across the city including those of the science museum.

2) State Required periodic Professional Development courses: 25-30 hourcourses with or without equipment followed by classroom lesson modeling. These courses were designed to yield not only higher quality science teaching in both content and methods, but also professional credit that teachers need to maintain their teaching certification and receive higher salaries and/or positions as their careers progress.

As in the STARLAB™ model, training using museum staff (and, in later years, master teachers from earlier courses) took place in the museum. And as in the proven STARLAB™ model, training included both content correlated to the curricular requirements in each grade and also inquiry-based and hands-on methods for teaching this content. An exchange of lesson models developed by the teachers in training resulted. Ultimately this exchange was expanded with a website for uploading and downloading shared lesson plans, tips, questions and evaluation models produced by trained teachers.

To ensure successful cross-over from the well-supported museum training environment to the classroom, lessons were developed that could be co-taught by the trained teacher and museum staff in each teacher's classroom. Teachers often scheduled these classroom lesson modeling sessions in classes with particularly difficult demands….students speaking English as a second language, students with physical or mental handicaps that challenged hands-on learning, behavior issues, or students with very uneven learning patterns who were on grade level in some subjects and behind in others.

Modeling the use of hands-on and inquiry-based methods as a way for each student to find their own place vis a vis science content in these challenging classes was electrifying for both students and their teachers. Teachers became "stars" to students, and students became "successful" in the eyes of their teachers. Everyone was better positioned not only to learn science, but also to work with each other across all subjects.

Highest Impact Correlates with Greatest Contact Hours

Outreach lesson modeling in the classroom (Photo credit: New York Hall of Science)

The two training models above have the advantage of reaching and changing the teaching content and habits of many teachers at a modest cost. The New York Hall of Science, for instance, was able to train 4,500 teachers per year using the per session rate that most schools have allotted in their budgets for teacher professional development. For these reasons alone, programs like the models above will likely dominate museum intervention in science education in the United States.

However, to actually change science education to the point where teachers routinely teach science more effectively, and, as a result, student test scores are higher, requires a more systematic supply of resources to teachers.

Three elements appear to be key:

1) Access to professional development on proven content and methods related to required curricula
2) Access to well-maintained equipment, including at least some basic equipment in a school lab
3) Ongoing access to an experienced science education "coach" who can help troubleshoot scheduling, content or methods problems, offer alternative lesson plans, encourage science teachers to take the ext step and serve as in-school advocates for quality science teaching -- especially when time or space resources beyond the usual schedule are required.

An ongoing model in New York uses a 3-year program to yield long-term, higher quality science education in a school building.

1) Year One includes:
    a. Goal setting with the principal and involved teachers
    b. Purchasing and setting up a basic lab (based on school budget realities)
    c. Initial teacher training
    d. Trained teachers working with their students
    e. Science museum-provided science education coach one day/week
    f. Teacher E-mail access to science coach
2) Year Two includes:
    a. Evaluating goals met & missed in year 1, and setting year 2 remedial and more advanced goals
    b. Introducing challenge-based learning (experiments designed by students)
    c. Introducing interdisciplinary projects (with social studies, technology, art, etc)
    d. Preparing students for exams
    e. Trained teachers working with their students
    f Science museum - provided science coach one day/week or every other week
    g. Teacher E-mail access to science coach
3) Year Three includes:
    a. Evaluating goals met & missed in year 2, and setting year 3 remedial and more advanced goals
    b. More consistent involvement of grades below and above target grades
    c. With teachers, identify and train student labtech volunteers to organize and clean labs allowing for higher volume use
    d. Trained teachers working with their students
    e. Science museum-provided science coach one

day every other week
f. Teacher e-mail access to science coach
g. Encourage communications between involved teachers
h. Identify master teachers to coach in years ahead

This third model is clearly the most effective in changing the quality of science teaching and student learning. For instance, in the 3rd year of the program, scores for disadvantaged children on mandated standardized tests increased from 60% to 71% passing. In another school with more economically-advantaged youngsters, but many of them with special needs, scores rose to 84% of students passing the state tests.

But until school districts themselves, with their superior financial resources, adopt the model, it will not be widespread across the students of a continent. That said, the proliferation of our science museums in themselves is a reminder that great ideas catch fire and replicate across the world. These models for increasing the quality of science education can also proliferate as each science museum picks them up, revises them for success in their own region, and expands their use.

Science museums as partners in state initiative for educational transformation

Most science museums/centers in India, especially those under the National Council of Science Museums (NCSM), are public funded institutions and as such are mandated to support formal science education in the country. Consequently, their annual activity calendars have, over the years, evolved to include programs like Science Demonstration Lecture (SDL) and Teacher Training Programs (TTP), which are specifically designed to carry out the museum's school science education agenda. These are now routine activities for Indian science museums/centers.

Whether such activities result in a real-time change in the quality of formal science education is a matter of critical evaluation and debate. But feedback from participants suggests that these activities make at least an immediate impact in the right direction. Although science centers in general are neither programmed to be nor are perceived as serious places for structured science education, which of course is the responsibility of their formal counterparts, the impact of their educational functions - the teacher training program in particular - need to be reflected in the quality of classroom transactions in the formal system. This is essential for public funded institutions like ours if we are to make a mark as agents for positive change in the formal science education set-up and to be considered indispensable entities in the country's education map.

In this context, it is pertinent to note that the National Curriculum Framework (NCF) of 2005 and the Right to Education Act (RTE) of 2009 made it incumbent on the state to usher in certain fundamental shifts in school education philosophy, its pedagogical structure and the quality of classroom transactions. Consequently, the state's education system needed to review and restructure curricular interventions in government schools in a manner that would be consistent with the following core transformational guidelines contained in NCF 2005.

From	To
Teacher-centric classrooms	Child-centered learning environments
Transmission of information	Construction of knowledge
Knowledge as given and fixed	Knowledge as it evolves
Teacher directs, guides and monitors learning	Teacher facilitates, supports and encourages learning
Learning by note	Learning through activities, exploration & discovery
Disciplinary, linear exposure	Multidisciplinary, divergent exposure
Memorizing	Understanding

Moreover, RTE 2009, besides making education up to the age of 14 (say, up to 8th standard) a fundamental right for all children in the country, makes the state responsible for ensuring access to equitable quality education across the spectrum of government schools in the country irrespective of their locations - urban or rural.

Together, NCF 2005 and RTE 2009 have certainly opened up new possibilities for Indian science museums/centers, whose educational practices are built on the same basic philosophy, to expand their domain of work and play crucial roles in the transformation of formal science education in the country.

BITM's Initiatives

Birla Industrial & Technological Museum (BITM) in Kolkata, the oldest constituent unit of the National Council of Science Museums (NCSM), has always been known as an educational institution. Besides itself, BITM also controls the operation of another four science centers of NCSM located in different districts of the state of West Bengal. This configuration (Fig.1) gives BITM the requisite structure to carry out its extensive outreach education programs throughout the state often in collaboration with the state's education department.

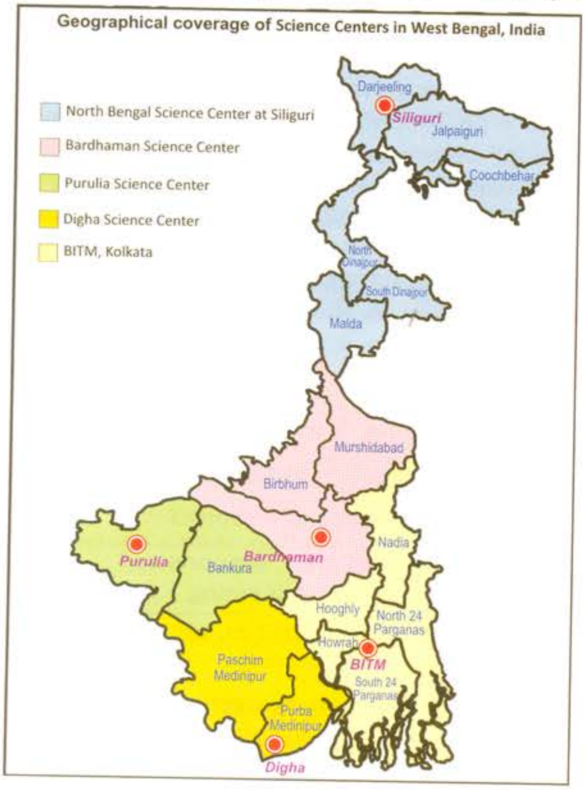


Figure 1: Science centers in West Bengal

Thus, when the state needed collaborators to help it implement the NCF & RTE guidelines and establish a child-centered learning regime in government schools, BITM was seen as a natural partner. The role of BITM in this new initiative was to help formulate a roadmap and to implement two pilot programs throughout the state of West Bengal:

1. Activity-based, child-centered learning in primary schools (up to class V)
2. Computer-aided learning in upper primary schools (class VI - VIII)

These initiatives are unique for science museums in India not because they deal with things that are different from the usual, but because these programs involve doing things a lot more differently in regard to their pedagogical structures, logistics and scale of operation. Besides these initiatives, two new facilities at BITM, namely, the Mathematics Gallery (2010) and the Open Science Laboratory (2011) also merit a mention in the context of the core issue of this article.

In this article, however, we will restrict ourselves to a brief description of the first statewide campaign for educational transformation undertaken by BITM and other NCSM science museums/centers in West Bengal in collaboration with the state's education department.

1. Activity-based, child-centered learning regime in primary schools

There are about 50000 primary schools in the state under the government which provide the first step to formal education for a child. Most of these schools are in rural and semi-urban areas spread across the 19 districts of the state. Besides raising these schools' infrastructure to the minimum level prescribed in RTE Act of 2009, the main point of concern and challenge for the administration is to enable these schools to ensure higher enrollment, lower dropouts and better classroom transactions. The task is enormous given the fact that there are funding constraints, infrastructural inadequacies and systemic inertia.

Despite the financial and systemic difficulties, the only way primary education possibly could change and improve in line with NCF & RTE guidelines was through 'capacity building' of the thousands of primary school teachers in the state. To this end, a 3-phase action plan was devised jointly by BITM and the state education department for implementation throughout the state with funding support under the Sarva Siksha Abhiyan (Education for All Initiative) of the government.

1.1 Action Plan

Phase1:Exposure-cum-Educational Visits to Science Centers in West Bengal

Primary schoolchildren and teachers visit science centers on regular basis for making them aware of, and excited about, hands-on activity-based learning.

Phase 2: Training of Primary School Teachers on 'Activity- Based Teaching/Learning'.

Teachers in batches receive 4-day training at BITM and its satellite units in West Bengal on activity-based teaching/learning methods during which they plan co-curricular classroom activities/demonstrations, develop appropriate materials/low-cost teaching aids, and participate in practice classes using the newly developed kits/activities. Teachers take the materials/kits developed during the training to their schools to conduct classroom transactions.

Phase 3: Setting up Activity Centers in Schools

For sustaining the activity-based child-centered teaching/learning practices, small activity centers need to be developed in primary schools which will have basic minimum facilities for creatively engaging the children in 'doing' things collaboratively with the teachers. Trained teachers will use the facility to develop more materials/kits/activities for their classes.

1.2 Implementation

The implementation of the first two phases of the action plan started in mid 2011. It began with students' exposure visits to science centers and was followed by the teacher training component. The idea behind this sequence was to pre-expose the teachers (who would receive training) and their students (ultimate beneficiaries of the training) to the hands-on and self-motivated learning environments of science centers before they started receiving training inputs from these centers.

Responsibility for implementation of the program in all the 19 districts of the state was shared among BITM and its satellite units in the following manner based on their location and infra-structural facility.

	BITM, Kolkata	**Bardhaman Science Center**	**Purulia Science Center**	**Digha Science Center**	**North Bengal Science Center**
DISTRICT	Kolkata	Burdwan	Purulia	East Medinipur	Malda
	North 24 Parganas	Murshidabad	Bankura	West Medinipur	Uttar Dinajpur
	South 24 Parganas	Birbhum			Dakshin Dinajpur
	Howrah				Darjeeling
	Hooghly				Coochbehar
	Nadia				Jalpaiguri
	6 districts	**3 districts**	**2 districts**	**2 districts**	**6 districts**

Table1: Districts covered by individual science centers

1.3 Implementation status

The targets for the year 2011-12 were: (i) exposure visits for all students up to class VIII from minimum 5 schools per district and (ii) training of the teachers from these schools. Between May 18, 2011 (when the program took off) and March 31, 2012 (end of plan year 2011-2012), the status of implementation was as follows.

No. of districts covered		No. primary schools included		Beneficiaries	
Exposure visits	Teacher Training	Exposure visits	Teacher Training	Students exposed	Teachers Trained
17	17	183	183	15839	707

Table 2: Implementation status as on 31.03.12

Conducting a statewide program of this magnitude, besides having to deliver museum's regular public programs, was a logistical challenge and demanded careful planning of the individual components. Key issues were:

For Exposure Visits
District-wise scheduling of visits to respective science centers, packaging and delivering tailor-made programs to the visiting children, serving them lunch, and ensuring that they went back excited.

For Teacher Training
Content planning, arranging input materials & tools for teachers to work with, district-wise scheduling of training programs at each science center, arrangement for lunch & tiffin for teachers, and also training of museum staff for the training program.

1.4 Teacher Training Programs : Structure & Content

The duration and batch size of each training program was restricted to 4 days and 35 teachers respectively in view of operational difficulties at the concerned schools as well as at the science centers. While schools could not afford to depute their teachers for more than 4 days, science centers with their limited strength of education staff could hardly do justice with more than 35 teacher trainees at a time. Moreover, larger batch sizes would also have entailed greater challenges regarding logistical provisions - accommodation, transport, and food - for the teacher trainees.

The training program focused on areas the teachers needed to handle in their classes, namely, languages, geography, environment, basic science & astronomy and mathematics. Museum educators, who were to conduct the training, first went through the primary school syllabus for these subjects. In each of them, topics or concepts which the teachers found difficult to transact in their classes through the usual 'chalk & talk' method were chosen as examples for designing training inputs. In order to ensure parity in the training program's deliverables across science centers in the state, concerned museum educators (trainers) from the participating science centers were included as trainees in the first training program at BITM which was conducted by its experienced education staff & officers. The main features of the 4-day training module were:

Goal Orientation & Motivational Inputs
The first half of day-1 was used to orient the teachers towards the ultimate goal of primary education as envisaged in NCF 2005 & RTE 2009 and the role of teachers in making this transformation possible.

The inputs included short video documentaries on 'success stories' by teachers elsewhere and motivational interactive sessions with educationists & state officials.

Image 1: Orientation-cum-motivational session

Image 2: Teachers watching a video documentary

Capacity Building Inputs

Teachers worked in groups under the supervision of museum educators for ideation and development of low-cost classroom exhibits or teaching aids, experiments, puzzles, activities etc. on selected topics in subjects of their choice. Necessary materials, tools and technical guidance (whenever required) were provided by the science center.

Image 3: Teachers working in groups

Image 4: Teachers developing classroom teaching aids

Teachers presented their works and products on the last day before an extended classroom that included museum staff, state officials and fellow teachers from other schools as students.

Image 5: Teachers presenting their works

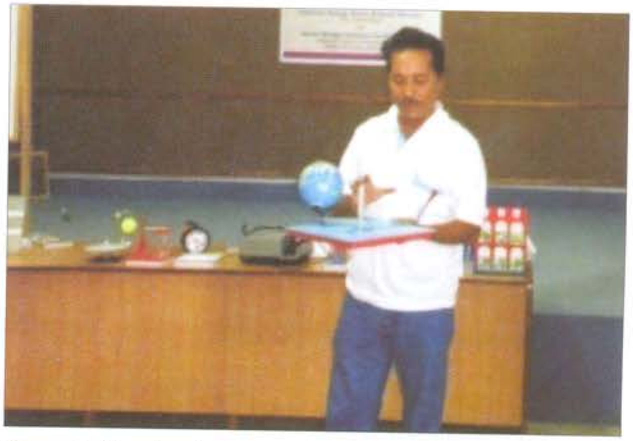


Image 6: Practice classes

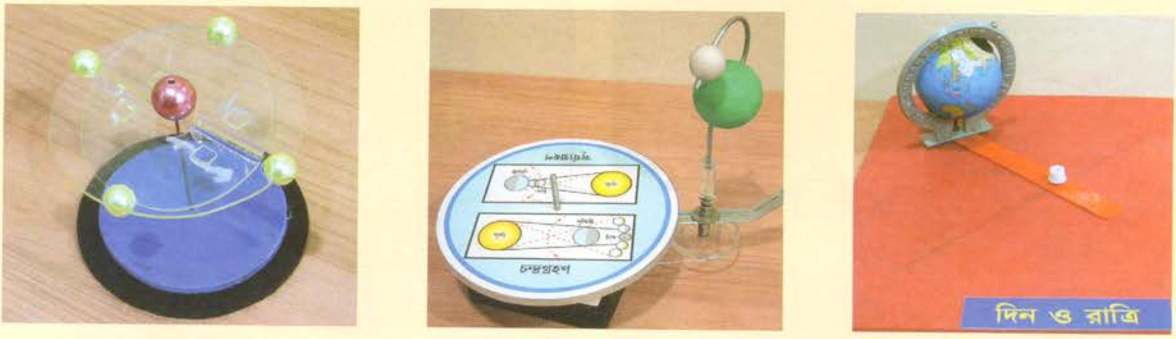


Image 7: Geography teaching aids/kits (for classes III and IV)

Classroom Transaction Inputs

From each school, 4 to 5 teachers joined the program in different batches and they took back all that they had developed during the training. In the process, each of the participating schools got 20 new classroom exhibits, teaching kits, experiments or puzzles, which provided them the basic inventory support to start the hands-on activity-based teaching/learning method. Following are a few samples of the items the teachers developed and took back.

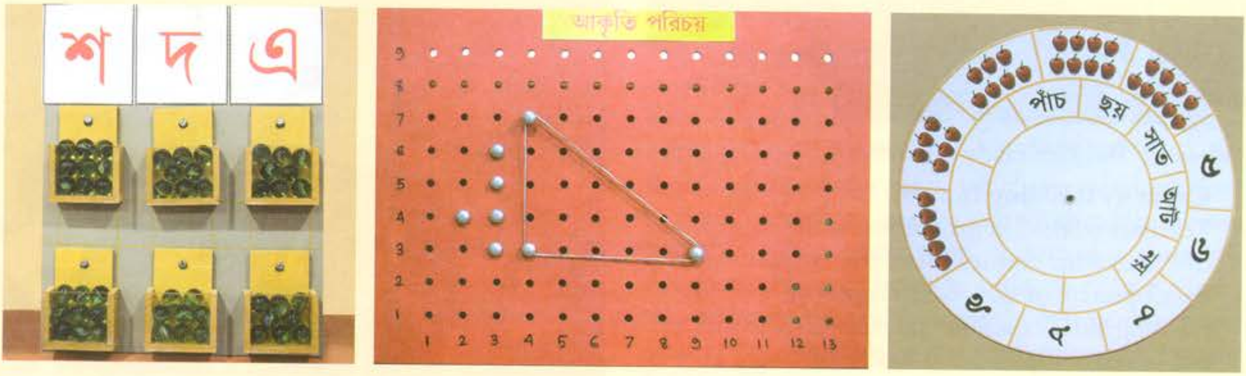


Image 8: Mathematics teaching aids/kits (for class I to IV)

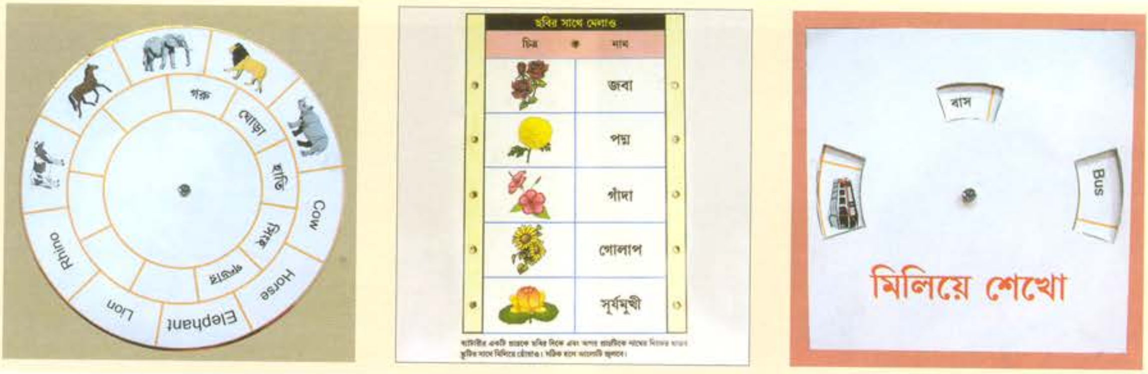


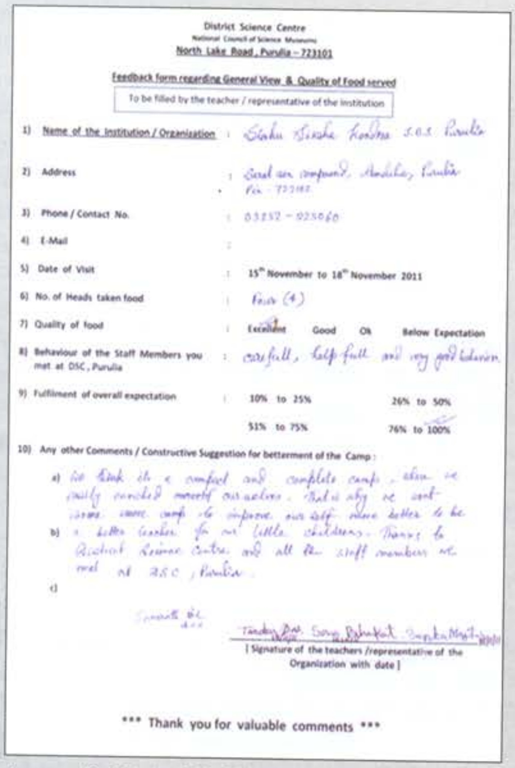
Image 9: Language teaching aids/kits (for class I to IV)

Besides developing these items for their classrooms, teachers also generated many new kit/activity ideas to work on after returning to their schools.

1.5 Feedback

Feedback from each teacher was collected for assessing the quality and appropriateness of:

(a) Logistical arrangements & museum staff services
(b) Training inputs
(c) Classroom kits developed



District Science Centre
National Council of Science Museums
North Lake Road, Purulia – 723101

Feedback form regarding General View & Quality of Food served

To be filled by the teacher / representative of the institution

1) Name of the Institution / Organization : Shiksha Siksha Kendra S.O.S Purulia
2) Address : Sarat [illegible] compound, [illegible], Purulia Pin - 723102
3) Phone / Contact No. : 03252 - 225060
4) E-Mail :
5) Date of Visit : 15th November to 18th November 2011
6) No. of Heads taken food : Four (4)
7) Quality of food : [✓ Excellent] Good Ok Below Expectation
8) Behaviour of the Staff Members you met at DSC, Purulia : carefull, help full and very good behavior.
9) Fulfilment of overall expectation : 10% to 25% 26% to 50% 51% to 75% [✓ 76% to 100%]
10) Any other Comments / Constructive Suggestion for betterment of the Camp :
a) We think its a compact and complete camp, where we easily enriched ourselves. That is why we want some more camp to improve our self more better to be
b) a better teacher for our little childrens. Thanks to District Science Centre and all the staff members we met at DSC, Purulia.
c)

[Signature of the teachers /representative of the Organization with date]

*** Thank you for valuable comments ***

Image 10: Typical feedback from teachers

An overwhelming majority of the teachers returned 'excellent grade' for all of these components and felt very positively about the utility of the training program in bettering classroom environment and transactions. A transcript of the typical feedback from the teachers reads like this:

"We think it's a compact and complete camp, where we easily enriched ourselves. That is why we want some more camps like this to improve ourselves to be a better teacher for our little children. Thanks to the science center and all the staff members"

1.6 Sustainabilty issues

Teachers had concerns about the implementation and sustainability of the hand-on, activity-based method of teaching in their schools. Their concerns could be traced back to the issues of

(I) systemic inertia against change
(ii) mission alignment and synergy of purpose among the stakeholders, namely, school's local administration, teachers, parents and the state education authorities
(iii) post-training monitoring, mentoring & funding support

Addressing these concerns will be critical for establishing the child-centered teaching/learning regime in the state on a firm footing. This will require sustained efforts by both the state's formal education establishments and the informal education institutions like science museums/centers operating in the state.

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NANOLAB : The Role for Science Centers in Capacity Building

• *Kanchan Chowdhury* • *K. Srinivasa Nehru*

Abstract

Nanotechnology will alter our relationship with molecules and matter as profoundly as the computer changed our relationship with bits and information. Nanotechnology is a new technology which is generating a lot of interest among academicians, practitioners and scientists. Critical research is being carried out in this area all over the world. Governments are creating policy initiatives to promote developments it the nano-scale science and technology developments. Private investment is also seeing a rising trend. Large number of academic institutions and national laboratories has set up research centers that are working on the multiple applications of nanotechnology. Wide ranges of applications are claimed for nanotechnology. This consists of materials, chemicals, textiles, semiconductors, to wonder drug delivery systems and diagnostics. Much interest in nanotechnology also could be because of the fact that enormous monetary benefits are expected from nanotechnology based products. According to NSF, revenues from nanotechnology could touch $ 1 trillion by 2015. However much of the benefits are projected ones. Realizing claimed benefits require successful development of nano-science and nanotechnology research efforts. That is the journey of invention to innovation has to be completed. For this to happen the technology has to flow from laboratory to market. The aim of the present article is to highlight the role of Science City, Kolkata to develop capacity building among general people and students for the responsible development of productive nanotechnology.

Introduction

It has been said that nowadays any significant problem in science requires interdisciplinary or rather more accurately a multi-disciplinary approach. More than any other areas of science, this holds true for the science of 'NANOTECHNOLOGY'. After the Information Technology and Biotechnology revolutions, Nanotechnology is another much larger industrial revolution in the making. Its effects upon the society are already being felt and it is envisaged that in the years to come this technology will impact upon each and every sector of our society including the IT and biotechnology considered earlier.

Nano-science is, at its simplest, the study of the fundamental principles of molecules and structures with at least one dimension roughly between 1 and 100 nanometers. These structures are known as nanostructures. Nanotechnology is the application of these nanostructures into useful nanoscale devices. Biologists, chemists, physicists and engineers are all involved in the study of substances at the nano-scale. Nanotechnology offers new engineering tools that can help us address the design problems associated with building better implants. In the context of biomedical engineering, recent technological advancements mean that we now have the ability to manipulate materials with nanometer scale accuracy. This allows us to create biomaterials with features the same size as the proteins and cells with which our implant interact. Nano-materials may also be used as active sensing elements or receptors, as transducing components (e.g. electro- or chemo-mechanical actuators), and even as electrodes in electronic circuitry and power systems (e.g. nano-wires). Developments in this field are taking place at a very high speed. Nanotechnology can be applied to every item we use in our day-to-day life to make it more users friendly and intelligent, whether it is toothpaste, clothes, phones, laptops, lubricants or medicines. In view of these factors all the developing and developed countries are aspiring to establish strong base for nanotechnology.

Nanotechnology in India

The field of nanotechnology is quite popular in most of the developed countries. India, China, Japan, Singapore, South Korea, and Taiwan are a few countries in Asia which have significant ongoing research projects in nanotechnology. It is one of the main science and technology priority areas for several government in the Asia-Pacific region. Budgets for nanotechnology R&D have been increased substantially and are more strategically allocated. As an outcome of such initiatives is the nano-filters already available in the Indian market for water treatment purposes. Cosmetics, detergents and drugs are also seeing remarkable application of nanomaterials at this point.

Nanotechnology in India is a government led initiative. Industry participation has very recently originated. Nanotechnology R&D barring a few exceptions is largely being ensued at public funded universities as well as research institutes. The Department of Science and Technology has started with a huge investment of about Rs. 1000 crores under the nano mission promoted by the government. This aims at supporting the research and development activities to come up with specific applications. The department of science and technology has introduced centers of excellence for Nanoscience and Technology to support researchers and scientists to test their materials for at a reduced price. The Department of Biotechnology, Defense Research and Development Organization, Board of Research in Nuclear Sciences and many such agencies and organizations are pumping in funds to support Nanoscience based research. A group of scientists from different research laboratories across India are putting in their efforts and are contributing to the development of different research projects in various research institutions. The Council of Scientific and Industrial Research, also known as CSIR has set up 38 laboratories in India dedicated to research in Nanotechnology. This technology will be used in diagnostic kits, improved water filters and sensors and drug delivery. Nanobiotechnology is being considered for direct delivery of drugs into the human body. This apart, the research trends can be numerous. Currently, nano-materials of different chemical compositions in biomedical applications are pushing the growth of this market. The research is being conducted on using it to reduce pollution emitted by the vehicles. Several Indian institutes have introduced degree courses in Nanotechnology at both the UG and PG levels. The areas covered in the Nanotech are Food and Beverage, Bio- Technology, Forensic Sciences, Genetics, Space Research, Environment industry, Medicine, Agriculture and Teaching. Department of Information Technology has a Nanotechnology Initiative division which initiated the Nanotechnology Development Programme in 2004. This program targets to create R & D capacity and infrastructure in nanoelectronics at national level. Under this programme two nanoelectronics centres have been established at IIT Bombay and IISc, Bangalore. The facility of IIT Bombay and IISc, Bangalore are being used by all nanoelectronics researchers in the country through Indian Nanoelectronics User Program (INUP).

Public Perception about NANO

The emergence of active nanostructures and nano-systems will challenge existing economic, social, and political systems in ways that are qualitatively different and much more rapid that previous technological revolutions. These effects will be a combination of the completely unfamiliar, the previously experienced, and the roughly analogous. How will social and political systems adapt to these changes and how will these technologies and their effects be understood and described? Many writers will use both familiar and new methods of scientific and popular communication to bridge the gap between public understanding, entirely new technological systems, and policy responses. Studies of the public's understanding of nanotechnology to determine their likely concerns and fears, and research on how to engage the public in a rational, informed dialogue about the risks and benefits of the technology are both underway,

Like so many areas of research, nanotechnology can be discussed quite easily with people who understand it, but can effortlessly mutate into a perfect nightmare when explaining it to people who do not. On many occasions, such people seem keen yet are completely dumbfounded by colourful explanations. There is a sense of dismay as they and others 'misinterpret' descriptions, ask seemingly unrelated questions, and generally find endeavours at explanation incomprehensible and bewildering. In the main, people are quite genuinely either oblivious to nanotechnology, or have a decidedly skewed notion of 'what it does'. This chasm within public understanding can be quite easily filled by other means, and the real difficulty is when that chasm becomes filled by marketing communications, rather than fact.

India has traditionally lagged behind in educating its masses and firing the curiosity of the future generations of technologists and scientists. Science and technology discussions have remained confined to universities and colleges. However, public awareness is critical to creating public opinion, which in turn has an impact on forming governmental policies and business opportunities. Negative safety perception of nano-scale materials is an area of concern for the nascent nanotechnology industry globally. Various agencies are already conducting studies to provide accurate safety related data and help shape public opinion on these nanotechnologies. In this context, the role of public opinion is critical to the development and growth of the industry in near term. The very public debate on genetically modified (GM) food is a case in point, which led to polarization of public opinion. Action is needed now to keep public updated on various issues related to technology to ensure acceptance of nano-enabled products by the public in future.

Role of National Council of Science Museums (NCSM)

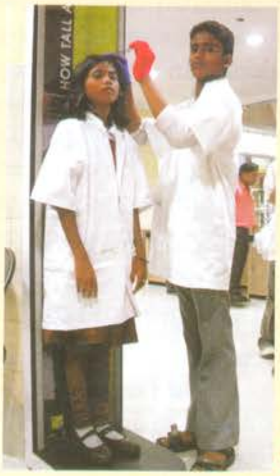
In our rapidly changing world, there is a great need for the public understanding of science and technology to create more science literate society at all age levels. Science Centres and science museums are vital and powerful media for popularization of science and creating a scientific temper across the globe. Science Centres are among those institutions that can play a role in showcasing science to common people.

NCSM has also taken up an initiative bringing nano-scale science to the public because of it's wide–ranging implications both within scientific disciplines and the society at large. One of the museum's main purposes is to offer experiences and products that interest and engage the public and present current science and technology topics in "do-it-yourself" format. Nanotechnology is particularly a challenging topic for museums because the science is very complex and museums sometimes do not have content experts. This thus creates a platform for sustained relationships between informal science education institutions like museums together with universities, research centres, scientific societies and individual researchers to offer activities in cutting edge science such as nanotechnology in do-it-yourself format for the general public using the expertise of the scientists. It also creates an opportunity for the scientists to reach out to the common man and, takes science communication a step beyond conventional approaches, initiating and encouraging a Public Understanding of Research.

NANOLAB in Science City

The NANOLAB aims to create innovative environments for the broad public to learn about and to discuss nano research by directly involving the actors of research themselves. We do this by taking the laboratory environment and the research work out of enclosed academic campuses and relocating them right in the midst of the public in science city.

Activities at a glance in NANOLAB at Science City, Kolkata
The NANOLAB was inaugurated at Science City, Kolkata on 5th November, 2011



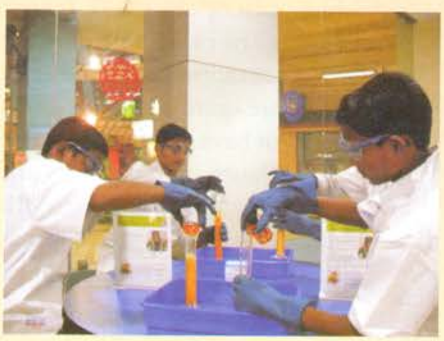


Fig.2. Students performing "Feel Nano!" activity

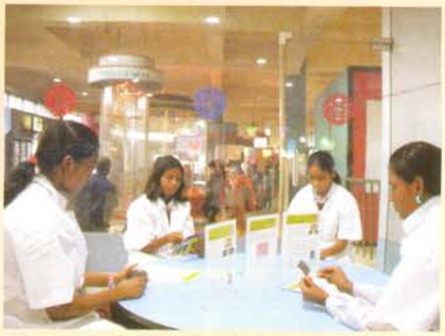


Fig.3. Students doing "Effect of Surface Area" activity.

Fig.1. Students measuring their height in nanometres

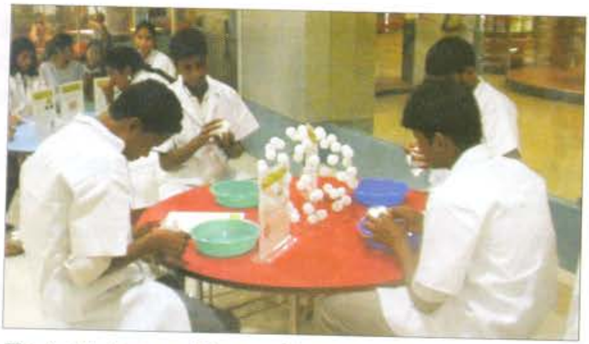


Fig.4. Students making models of Buckyball

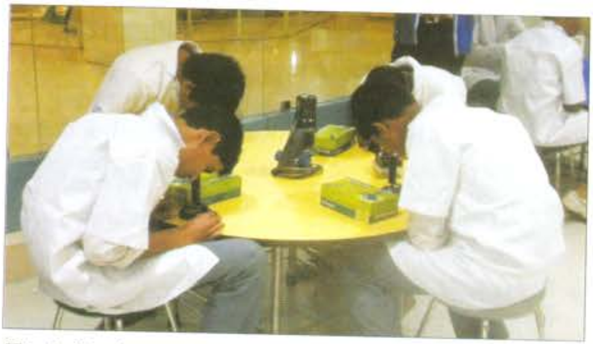


Fig.5. Students working with microscopes

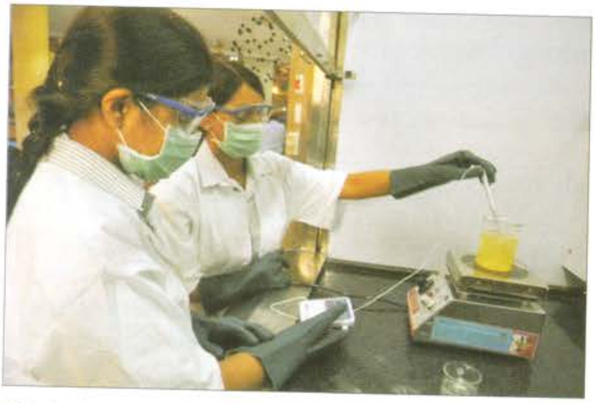


Fig.6. Students preparing nano colloid

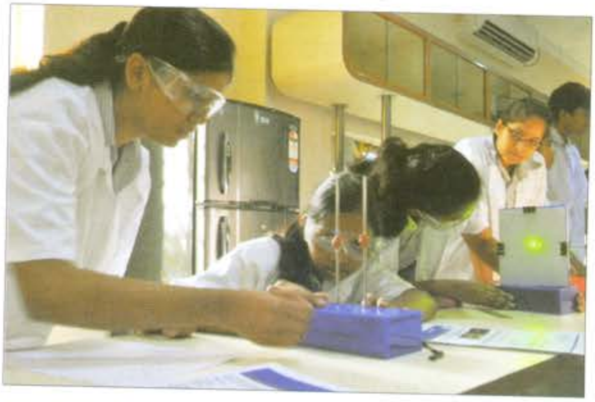


Fig.7. Students measuring the thickness of human hair in nanometres

NANOLAB will also establish new role models for choosing science as a career: young adults keen to take science as a career will be able to discuss various aspects with young researchers who themselves made this decision recently and also the researchers already in this field will learn that communication is a self-evident part of their professional identity.

Thus, NANOLAB pushes science communication to its extreme, combining communication and research in a powerful way and responding to the need for more transparency and accessibility in science. Furthermore, the strong synergetic network approach of the project enables contents and models to be developed for further distribution and implementation in educational and scientific communities.

Typically, scientists act in two completely different modes of operation which are completely independent of each other: on the one hand they conduct research within their scientific community, whilst on the other they separately explain or "demonstrate" their work to the lay public. This approach, however, often leads to a top-down science communication which can easily overwhelm or confuse the average person.

Having a full-size, perfectly operational research lab in the public space of the Science City is an idea that breaks right through the conventional lines of demarcation that normally seal off science from society as a separated subsystem. As this approach requires both experience in running scientific research and in dealing with public discourse, a close networking of institutions from both fields is necessary to the benefit of all.

NANOLAB can help in creating innovative spaces for spreading excitement and insights about nanoscience around the public. The major two activities of NANOLAB include -

Inform the public about Nano: A wide range of activities including publication of catalogue of educational programs, activities and demonstrations, organizing various awareness programs and debates, seminars etc. to raise public awareness, understanding and engagement with nano. Business executives, educators, policymakers, and consumers can make important decisions about nanoscience and technology applications in the coming years, and the more informed the public can be about nano; the better those decisions are likely to be.

Month	No. of shows	No. of general visitors	No. of students	No. of hands on activities	No. of Special visitors	Total number of visitors
Nov, 2011	36	239	720	116	10	959
Dec, 2011	100	1414	792	--	10	2206
Jan, 2012	117	998	990	--	8	1988
Feb, 2012	83	470	1405	--	10	1875
Mar, 2012	95	704	366	--	8	1070
Apr, 2012	113	1047	276	20	25	1323
May, 2012	70	706	147	--	5	853
Total	**614**	**5578**	**4696**	**136**	**76**	**10274**

Activities at a glance in NANOLAB at Science City, Kolkata

Get kids interested in science: Nano Lab is an opportunity to showcase what is great about science and science careers. In this lab students will learn about cutting edge science, possible new careers, and will visit science labs and meet the researchers.

A MOU has been signed between Science City, Kolkata and Science City, Naples in Italy for organizing collaborative programs for school students on Nanoscience and technology with duration of six months. The aim of such collaborative programs is develop the basic skills among school students and to orient them towards research in new fields of science and technology in international arena.

Challenges faced in India

The field of nanotechnology however faces many challenges in India. One of the important factors that prevent different agencies from funding various research activities is the longer time taken by the products based on nanotechnology to enter into the market. In the present fast and dynamic world technological advancements takes place very frequently. Such frequent technological advancements makes research equipments and tools out dated. More over the latest equipments are becoming expensive which makes it further difficult for researchers and research agencies to carry out research projects within the stipulated time.

India, with its more than one billion people, a wide landscape and a diverse socio-economic base, has tremendous possibilities for any technological intervention including nanotechnology. Nanotechnology in India is expected to unleash the full force of India's creativity and its craving to satisfy all its basic needs, to catch up with the world, rather to surpass the world.

Career in Nanotechnology

The changes happening in Nanoscience will impact almost all the sectors, which opens up huge opportunities for candidates with degree in Nanoscience. Before going into the area of nanotechnology, the candidate should make sure that he or she is a master of the core field which he or she belongs to. In the present day scientists and researchers are associated with developing commercial products through the application of nanotechnology. So it will be useful for candidates to pursue doctoral degree in the area of interest. But before this a proper training, awareness and education is utmost important and so the major challenge for this NANOLAB in Science City, Kolkata is to impart effective and fruitful education and training to the student's communities for developing highly skilled human resources in this field.

The opportunities in the future

Nanotechnology will have an impact on the average Indian. After all how many of us know that today's detergents or hard-drives are products of nanotechnology? It would make the lives of a common man way simpler, smarter and multi-nodal than what it is right now. In terms of employment opportunities, sophisticated nano-products would take a few decades to come into existence.

Today nanotechnology is mainly concerned with research and so the opportunities for research activities for any one in this field is very high. Since nanotechnology has tremendous potential for applications in the day to day issues, the research in the field will continue as long as human beings exist in the planet. There is huge gap between demand and supply in different industries as far as materials are concerned. It is expected that nano materials will bridge the gap between demand and supply. Industries can collaborate with various government research institutions to incorporate nano technology in their products.

Looking at the progressive prospects of Nanotechnology in India, Nanobiosym Inc., a US-based leading nanotechnology firm is planning to set up India's first integrated nanotechnology and biomedicine technology park in Himachal Pradesh. Nanotechnology has certainly acquired an essential position in the Indian Economy and Scientific Research Department and it is expected to reach the pinnacle of Development thereby making India a role model for the countries of the world.

The future possibilities of NANOLAB include development of new educational activity kits in Nanoscience for other science centres and schools, popular science lectures by eminent Scientists, multimedia shows on nanoscience, more collaborative programs with national and international nanoscale research institutes. This NANAOLAB first of it's kind in the network of NCSM will address national need to inspire and prepare our young students to explore the growing educational and professional opportunities in nanotechnology.

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Rev. Felix Carey: Medical Missionary and Linguist

Prof. Chittabrata Palit

Rev. Felix Carey of Srerampore: Medical Missionary (1786-1822)

Felix Carey was the eldest son of Rev. William Carey who can be called a prodigy of his times. The Carey family arrived in Bengal first as Manager of Woodney's Indigo Concern in Malda, but from the very beginning, they could not adjust to the climate and food of the region. Felix and his mother became seriously ill. They were afflicted with dysentery and Field's life was in great danger. Though Felix survived; his younger brother Peter succumbed to the disease. They also suffered from the chronic poverty which affected their physical and mental condition. Finally they came to Serampore on 10th Jan.1800,which was then under Danish flag. Carey rejoiced, "My whole family enjoyed much better health than we did on our first coming. My children can speak Bengali nearly as well as the natives."

Carey had already collected a printing press, Bengali types, papers etc. and was ready to start printing his Bengali translation of the New Testament. The Serampore mission was launched at the same time. At this time four missionaries Marshman, Ward, Bransdon and Grant had come to Serampore and joined him. Felix was put under Ward's care for proper Christian grooming. Ward was very fond of him and nicknamed him,'a tiger'. Felix was by then 14 years of age and ready for religious conversion and imtruction. Felix even enquired with tears the way of Salvation.[1]

Felix as a Printer

Ward became his friend, philosopher and guide and on 20th Dec.1800, Felix together with the first convert Krishna Pal was baptized in the Ganges and then became a full-fledged missionary preacher at the raw age of 14 hears 3 months. Initially Father Carey was in charge of translation work, medicine and finance. Felix assisted Ward in printing in which he had immense talent and ability. As an expert printer, compositor, and proof reader, Felix continued learning Sanskrit, Hindustani and Bengali with the help of Munshis. He even took part in preaching in the neighbouring villages. People were attracted by his fluent Bengali. Apart from village preaching, he was also in charge of a Sunday school, the first of its kind in India(1802).His health broke down due to heavy work, but he recovered and in 1804 got married to Margarette Kinsey at Calcutta. After this marriage, his health remained steady and he now turned his attention to learn medical science. One doctor Taylor at that time came to reside at Serampore. He became the medical tutor of Felix. Dr. Taylor collected an unclaimed deadbody from the locality and taught Felix dissection and anatomy with its help. But Dr. Taylor did not stay for long and went over to Bombay to take up missionary work over there. After Dr. Taylor's departure, Felix continued his studies at the Calcutta hospital. This training was of great help because the Serampore missionary was planning a medical mission for the surrounding villages. After the death of Dr. Thomas in 1801 and departure of Dr. Taylor, there was no medical man in the mission. Felix was the only qualified person indispensable for printing and translation and for medical work. But Felix wanted adventure abroad and soon took up the mission's work in Burma. His stay in Burma was a disaster, though he gained popularity in the court of Ava, and made forays into East Bengal but in private life he lost his first wife, his second wife got drowned and the third fled. He finally returned to Serampore in 1818 and resumed his work at the press. From 1818 till his death in 1822 he became a medical missionary and prolific writer of science in Bengali in 'Dig Darshan, a Bengali fortnightly in Serampore. It was at this time that he contemplated a Bengali Encyclopedia, Vidyaharavali in six volumes. All scientific entries were written by him. His most famous work of Anatomy was in the first volume, the details of which will be given later. This ambitious project of Felix originated from his father's desire to teach western science in Bengali to the Bengali students and to establish a medical faculty in the Serampore college with govt's approval. Felix was entrusted with the task of preparing a text on anatomy. The columns of Vidyaharavali bears testimony to his work. The second volume was on western sciences also written by Felix. He died when he planned the third volume on medical jurisprudence. It may be noted here that he wrote more than 20 articles on scientific subjects including one on psychology.[2]

Felix as a scientist

For a long time Felix was engaged in the medical service in Serampore, Calcutta and Burma and his rich experience was suitable for the project. Felix selected anatomy as the first volume of the series. This choice however laudable was fraught with insurmountable difficulties. For lack of suitable terminology in Bengali of Western scientific and technical terms, but this forbidding task was still attempted by Felix with the help of his father and two renowned Bengali scholars, pandit Sreekanta Vidyalankar and pandit Kabichandra Tarkashiromani. The first volume of the Vidyaharavali was completed on anatomy by Felix Carey translated from Encyclopedia Britannica from its fifth edition. In the words of Sushil De-"It is divided into 3 parts, each containing several chapters and each chapter divided into sections which are sub-divided into paragraphs or articles. The first six chapters deal with Ostiology, 2nd part in 12 chapters with comparative Anatomy, while the 3rd part traces the history of the science and gives the list of principal books on the subject of Anatomy, Medicine and Chemistry with the names of their authors and brief account of their contents. The whole is rounded off with a glossary of technical and difficult terms. This glossary in certain respects is the most interesting part of this entire treatise. This enormous volume was not received as very commendable as its style was stiff and uninteresting. The unintelligible technical terms and phrases makes it difficult to follow the books. But it certainly bears testimony to the compiler's learning and untiring industry.[3]

Vidyaharavali received a very poor response from the enlightened native society, especially the opulent class who were eager to have the children taught in the English medium to isolate themselves from the common people. Felix's book was too costly for the poor middle class people, among whom eagerness of learning was maximum. Only a few of them were able to collect copies of Vidyaharavali. Only the missionaries who were labouring through the Calcutta School Book Society supported such noble endeavour. From the records of CSBS, it is found that only 114 natives subscribed to this book. But Rev.James Long mentioned in his catalogue that there were 300 native subscribers of Vidyaharavali.[4]

Aid to the lepers

The plight of the lepers who were rejected by their families and society is a pathetic scene witnessed by William Carey. With pained heart, Carey relates what he saw in Katwa in 1812.

"A pit about ten cubit in depth was dug and a fire placed at the bottom of it. The poor man rolled himself and struggled hard for life. His mother and sister, however thrust him in again, and thus a young man, who to all appearance might have survived several years, was cruelly burned to death. I find that the practice is not uncommon in these parts. Taught that a violent end purifies the body and ensures transmigration into a healthy new existence, while natural death by disease results in four successive births and a fifth as a leper again, the leper like the even more wretched widow, always courted suicide."[5]

The lepers were also drowned so that they would be reborn with healthy bodies. Carey called this disease as the 'Great Sickness'. When he and Thomas tried to help the lepers, they also fed them with spiritual food along with medicines for their sores. Perhaps it was this which angered the critics that Carey waited for an opportunity to convert and what better time than when they were in need. William Carey probably looked upon these lepers as the ones Jesus had compassion upon, and his missionary zeal could not be hidden or denied when his services to them were considered. The missionaries once again used their vital tool, the Friend of India to publicize the pathetic state of the lepers, urging the people to render their kindness to them. Daniel Potts, in his book titled Baptist Missionaries in India 1793-1837, quotes from British records that even though George Smith and other biographers of Carey claim that Carey did not rest until an asylum for lepers was founded. There is no evidence for the same.[6]

In addition to the above concerns, we also need to mention Carey's tireless service to the cause of abolition of slavery. This caught their attention when they witnessed the sale of children as if they were items of sale as goats or poultry. Once again James Peggs who was their propagandist, resounded the protest of the Baptist missionaries to abolish slavery. It was effected by Acts in 1843 and 1860 to declare that slavery was illegal. The protests of the missionaries however found early result when slavery was abolished in the West Indies where the cry was raised at the same time.

One can debate for a long time on the person who abolished the evil practices such as infanticide, Sati, slave trade or the exposure of the sick and the dying without coming to a consensus. Different writers have ascribed the honour to different people, like Raja Ram Mohan Roy, Lord Bentinck, and some have also given William Carey, the credit. What is important to realize is that feeble voices protesting against the inhuman practices were raised from time to time but they did not draw the attention of the Government. William Carey did exactly what was needed. He succeeded in drawing the attention of the Government through their publications in 'Friend of India and Samachar Darpon'. He learnt the language of the people that brought him closer to understand their plight while this can be considered as his advantage, the fact that he was a missionary, a zealous Christian missionary was his disadvantage. The love that he showed to the people in fighting for them and their liberation from human clutches was suspected by the caste Hindus who were afraid of their religion being uprooted from them. Even though they respected and admired the work of these missionaries, their fear remained. In their opinion, Carey was convinced that the introduction of learning would lead to the gradual dissolution of many of the popular notions of Hinduism thus paving the way for removing the last minute hesitation on the part of Ram Mohan Roy in the abolition of Sati. In my opinion, it would amount to an example of utmost ingratitude to deny William Carey any credit in the introduction of social reforms of his time, as it was he who prodded the otherwise passive Govt. to take a stand on such issues.

Carey's contributions to the social reforms in India mark the synchronisation between preaching and practicing the gospel. The Nazareth manifesto comes alive in action during the period of the Serampore Trio's life and work in India. Compassion gains a new meaning. It is not merely sympathizing with the suffering but participating in suffering till the end. The stand that Carey takes i.e. to be with the oppressed, marginalized and against the oppressor, in fact reflects on the type of God he believes in. The relevance of this truth is realized in our theologising when God of the oppressed, God who suffers with us and a God who liberates us from every yoke of bondage. When this truth and significance stand as a norm to evaluate our values, lifestyle, our theologies there is an opportunity for corrective theology.

It seems that history needs rewriting just as much as our theologies. History itself can be oppressive if it fails to be open for correction. Straightening of history is of great significance for its own sake, for our mission's sake and for our theology's sake. It is our hope that William Carey kindles in every heart, not only awe, admiration and wonder but also a challenge, commitment and service to those who are deprived of their basic human rights, oppressed, discriminated because of their sex, colour, caste, creed and race. To this goal is centered all reflections and historic accounts of William Carey, the FRIEND OF INDIA and Felix Carey to whom this article is dedicated.[7]

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Waterpower Technology in India: Traditional Knowledge

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Introduction

One of the areas in which India's traditional knowledge systems have developed and survived from pre-historic to contemporary times is that of the development and management of water resources. In the context of South Asia, a wide variety of engineering and water-related systems were developed at different geographic locations over different periods. Though the early history of the watermill in India is obscure, the ancient Indian texts dating back to the 4th century BC refer to the term cakkavattaka (turning wheel) and subsequently different forms of water lifting devices. According to Greek historical tradition, India received water-mills from the Roman Empire in the early 4th century AD. Around 1150, the astronomer Bhaskara Achārya observed water-raising wheels and imagined such a wheel lifting enough water to replenish the stream driving it, effectively, 'a perpetual motion machine'. The same machine has given rise to Traditional watermills, which have been in use in the Indian mountain region since time immemorial. This device that harnesses waterpower for local production is a symbol of local technical excellence and the traditional wisdom of the people inhabiting the mountain region. In India, experts estimate that the watermill originated somewhere in the northeastern region around the 7th century BC. The system worked harmoniously with nature for over 2700 years and is abundantly scattered across the Himalayas.

Water-lifting devices in ancient India: Origin and Mechanism

As it is in modern times, agriculture was one of the main industries in ancient India. Irrigation has been one of the chief needs in developing agriculture. The oldest evidence of the existence of water-lifting devices is furnished by the 'scored pottery' unearthed from the Mohenjo- Daro and Harappa excavations. In the opinion of Sir John Marshall, they were made for attachment to an appliance for raising water, similar to the modern use of water-wheel in Near and Middle East.

Mention of wells, canals and dams in the Vedas indicates that Vedic Aryans did not depend on rainfall alone for agriculture. Besides artificial devices, in areas where natural supply of water was scarce, people had to depend solely upon deep-sunk wells. The hymns of Ṛgveda and Atharva Veda mention aveta signifying a well, aśma chakra which was a mechanical stone wheel device for drawing water from deep wells as well as ghaṭi-chakra or ghaṭiyantra for lifting water.

As early as the fifth century B.C., mechanical devices, worked by animals, particularly bullocks, were known and used in India. In Aṣṭadhyāyi, Pāṇiṇi, the celebrated grammarian, has mentioned the yugavaratra to mean the yoke and the rope or strap by which the bullocks were driven for raising water. He has also described two types of wells, the karkandhu and the shakandhu, the latter being a type of water-wheel probably used by the Śaka tribe. In order to lift water from wells during irrigation, udamchana, a large earthen bucketwas used.

During the reign of Chandra Gupta Maurya there was an elaborate system of irrigation as is attested by Kauṭilya'sArthaśāstra and the Indica of Megasthenes. Megasthenes has described at length about the facilities provided for irrigation, while Arthaśāstra records the variation of water- rates with the modes of irrigation, which were four in number, viz.

* *Hastaprayartima* - drawing with the hands and carrying it to the fields in pitchers, etc.,
* *Skanda* - the shoulders or the necks of bullocks,
* *Śrotoyantra* - a mechanism for lifting water in channels flowing into the fields,
* *Udghāṭam* - the water-wheel for raising water from river, etc.

Bhoja's *SamarāṅgaṇaSūtradhāra* describes a few types of water machines (vāri-yantras), but does not provide a systematic classification of all of them.

Water lifting mechanisms were prevalent in the southern part of the Sub-Continent from the very early centuries of the Christian era. The application of water-lifters and other simple devices in South India is mentioned in the following Tamil works such as

* *Ahanāṇūṛu*, a *Sangamliterary* work,

* *Maduraikāñchí*, one of the ten Idylls *Pattuppāṭṭu*. Here it is mentioned that *tev* and *edā*, denoting palleaf baskets, were responsible for the continuous water-logging in the paddy fields.

* *Silappadikāram and Maṇimēkhalai*, the two Tamil epics. In the former, the poet *Illańgo Adigal,* while giving a detailed account of the *Kāvērí* describes the modes or devices of irrigation, particularly the bucket, the water-lifts and palm-leaf baskets,

* The *Periyapurāṇam*, a compendium of biographical sketches of the 63 *Śaivanāyanārs* (saints), also makes reference to *edā-pēridā-k-kollamun-kavitu*. Here the term *pēridāstands* for a 'large basket'.

A number of early Tamil epigraphs mention *ēttapuḷam* and *ēttapādam* to categorize lands irrigated by means of picotahs (water-levers). Depending upon the extent of wet-fields under irrigation, *kuṛṛēttam* indicates 'small picotah' and *pērēttam* stands for 'large picotah'. An epigraph from Tiruvoṛṛiyūr (Madras) of PallavaKampavarman tells of *Tengēriinnilattirkēnālēttameduppadāga*, the cultivable lands on the banks of the tank *Tengēri*, to be irrigated by four picotahs. Another record from the same place of the Pallava king Aparājita mentions about 'the land irrigated by two large picotahs' which by their description must have irrigated large area of land. It also refers to two *jala-yantra* (water-levers), which were apparently added as additional means of irrigation in the village. The Rāyakoṭa plate of Skandaśiṣhya (fourth year) records that such water-levers were also known as *ētta-ppādam*.

In the light of all literary and epigraphic evidences, the methods of irrigation employed by the ancient Indians can be arranged under three broad heads as follows:

Intermittent or discontinuous water-supply from streams, canals and wells

The three types, the basket, the bag or bucket moved by pulley-wheels and the water from wells by animal power, come under this category.

* *Basket* - There are definite instances as proof of the widespread use of baskets, in ancient South India. Piḷā or edā, otherwise known as iṛaikūdai in Tamil, was a basket specially employed for bailing out water from deep channels or streams to nearby fields. It was knitted out of palm-leaf to get the required shape of a basket (kūdai), with a thin rimmed wide mouth and a shallow bottom. The common utilization of palm-leaf baskets, in ancient South India, as it is done even today was due to the easy availability of palmyra trees and that the baskets were fairly leak-proof and durable. In the Northern region its use was completely absent probably because of the non-availability of palmyra trees.

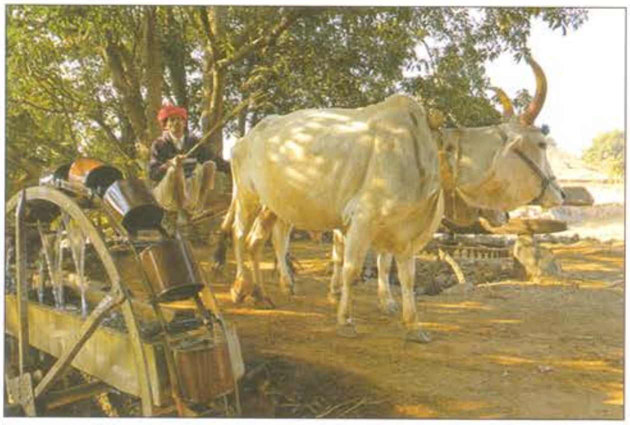
* *Pulley-wheels* - The earliest reference to ancient Indian pulley-wheels of stone or wood, similar to those used in modern times, found in the Ṛgveda was known as aśma chakra. Here the water was raised by a wheel (chakra) of stone (aśma) with a pail (kōśa) attached to it. When raised it was poured into troughs (āhāva) of wood. In the Tamiḷ country, the wells fitted with such pulley- wheels for drawing water from them were known as kiḷār. Among the devices invented by the ancients, the pulley-wheel was the simplest one for practical purposes. It was a one-man job to draw water from the well for increasing the flow of water. It is thus obvious that the pulley and rope gave rise to the 'mhōte' of Northern India, which was used for irrigating fields, the rope being drawn by bullocks.

* *From wells by animal power* - Irrigation from wells by means of animal on draught-plane came to be known and practiced in ancient India as early as the fifth century B.C., as indicated by the word *yugavaratra*, meaning the yoke and the rope or strap by which the bullocks were harnessed for raising water from wells. Though it is clear that harnessing animals to the task of drawing water from wells had been conceived early, as is evidenced by the mention of *skanda*, meaning the shoulders or the backs of bullocks in *Kauṭilya'sArthaśāstra*, yet no ancient representations are traceable of a beast pulling up the bucket. Since *kapilai-ēttam*, the water from wells worked by bullocks is not mentioned either in early *Tamiḷ* works or in the numerous inscriptions of South India, it may be assumed that this important method may have been introduced in South India with full improvements, at later

stages as an additional means of distributing water for irrigation.

In a typical bullock mhōte, a pair of bullock move down from the slope, specially constructed to the wall of the well, lifting behind them a bucket or a leather bag which is discharged into the connecting channel by means of a rope. After discharge, the bullocks walk up the slope until they reach the top by which time the bucket will have reached the surface of the water and got filled; and then the process is repeated. This method is not free from the application of human labour, for the man who sits on a seat in between the animals has to properly conduct the animals during the process. In spite of its discontinuous and insufficient water flow, the time consuming nature of animal operation and overall low efficiency, this mode of irrigation stimulated the invention of the semi-mechanical and full mechanical devices.

Irrigation from wells by means of animal on draught-plane came to be known and practiced in ancient India as early as the fifth century B.C.



Present existence

In the rural area around Udaipur there are many water mills used to irrigate the lands. This one is powered by two cows. The farmer is behind them yelling to keep the cows going.

Semi-mechanical Devices: The Balanced - bucket

In ancient India two types of balanced-bucket, semi-mechanical in operation and design, were in use. One was efficiently operated with counterweight, and the other one balanced by the weight of human body.

* *With counterweight* - Referred to as the tēra or the tiryakayantra in the Ṛgveda, the semi-mechanized water-hoist was known as shadoof in Egypt, dāliya in Iraq, picotah/ēttam/rāṭaṇamin South India and lāt in parts of North India. It was worked by a pair of long, tapering and nearly horizontal beam fixed across two vertical pillars about 8 to 10 feet high, set up less than a yard apart above the ground. Sometimes, granite stone pillars acted as the vertical beams instead of palmyra ones. A leather bag of considerable size or a bucket made either of earthenware or metal is hung from the larger and thinner end of a rope or thin bamboo pole, while a block of stone was secured tightly to its shorter and thicker end, as the counterbalance. According to Ernest Mackay, the large sized bricks (11.7"x5.7"x2.73") having a cut-hole of about 2.5" diameter in the centre, recovered from the excavations at Mohenjo-Daro 'may have been used as a weight for some form of apparatus', possibly the water-lifting devices.

* *Balanced by the weight of human body* - This is the same as the previous one, the only difference being that it is operated with the application of human labour. The tapering horizontal pole is worked by trampling along the pole instead of the counterweight placed at the other end. The man who stands and tramples the pole must have sure balance and adequate previous experience to operate the device and therefore it requires considerable practice. It was commonly used in parts of South India, including Madras.

The change from the system of animal power to mechanical was an achievement, but the output was limited by the depth of the well. The shadoof with its rhythm of rise and fall, dip and empty, to which the ancient labourer must have sung, as does his modern descendent, can prove to be much quicker and more efficient than any non-mechanical type of water-lift.

Continuous water supply by water-lifting machinery

Wheels of pots or water-wheel - Technologically speaking, the next and last stage was the fully mechanized water-hoist moved by a water-wheel or wheel of pots, put into practical application as early as the second millennium B.C. From the pottery excavated at Mohenjo-Daro, Sir John Marshall opines that 'some arrangement for drawing water for irrigation, by means of an endless rope working over a wheel, with pottery vessels attached to it at intervals was in use in Sind and other parts of Western India from early times, though it may not have taken the form of modern wheel'. But the excavation finds at other Chalcolithic sites unmistakably show that 'only one type of jar has been found broken in large numbers. Jars of this kind average about six inches in height, have a pronounced, pointed and deeply scored belly and are certainly too large to be grasped comfortably in one hand'. According to E. J. Mackay, 'they are frequently coated with a thin cream wash, they all have deep spiral grooves round the middle, which would have served to give greater security if they were attached to some kind of water-wheel'.

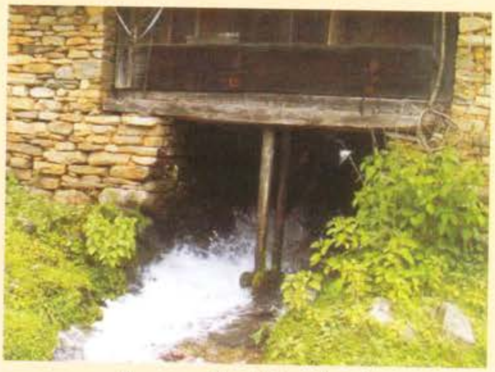
The spade of the modern archeologist has not exhumed relevant material evidences, other than pottery, to throw light on the water wheel and its essential parts. So we are unable to reconstruct the actual model of the water wheel used in the Protohistoric period. Yet, the documentary references of ghaṭi chakra in the Ṛgveda and udghāṭam in the Arthaśāstra prove that there was an indigenous method of raising water by using wheel of pots and having specific names from very early time.

Sir John Marshall believed that the modern Persian wheel, exclusively confined to Balūchistān, Sind and the Punjāb and some parts of the Bombay presidency, may have been an improvement introduced into India from Persia. Had this been true, it would have retained its original name, of dauwaryah or charkidauwar. Since the device still bears the same Sanskrit name ghaṭi chakra to the present day, it is reasonable to infer that the wheel of pots had its own independent origin in India in the ancient period.

Traditional Watermill of Himalayan Region

Watermill is a centuries old technology, which is still widespread over the hilly territories of Uttaranchal, Himachal Pradesh and North East India and other Himalayan region of Nepal, Tibet and Afganistan. The origin of water powered mill for grinding cereals were adapted to mountain areas with streams rushing down gullies and their design was perhaps suggested as much by experience of waterwheels used as water lifting device. We might expect the first water mills to have seen made in a mountainous districts in the Himalayan mountain range, where people had experience of all these devices and also mill stone for rotary hand mills.

Himachal Pradesh



Arunachal Pradesh

The Himalayan region covers mainly eight countries i.e. India, China, Nepal, Bhutan, Bangladesh, Myanmar, Pakistan and Afganistan. In Indian perspective Himalayas consist of four ranges extending about 2 500 kilometres from Arunachal Pradesh on the Tibetan border in the east to Jammu and Kashmir in the West. The mountains in the range are between 5000 metres and 9000 metres in height and fall steeply through sheer-sided gorges and river valleys to the northern Indian plain over only a few hundred kilometres. Nineteen major river systems, including the Brahmaputra and the Indus, rise among the mountains. The physical geography provides excellent hydropower potential, which was recognised very early in the history of use of waterwheel as motive power for mechanical systems and modern day hydropower.

Life in mountain ecosystems all over the world have certain commonalities such as fragility, inaccessibility, marginality and diversity and these have a huge impact on the everyday life of people living there. Survival needs in these difficult and unique biophysical conditions have resulted in the evolution of 'human adaptation mechanisms' or the knowledge systems. These systems and practices have emerged through the process of continuous observations, experiences and experiments and adaptation by the people. Himalayan region is also a rich storehouse of such practices, which have evolved over the years and form a crucial component of their survival strategies in these difficult situations.

Chherna village in Himachal Pradesh

Saili village of Kathua District, Jammu & Kashmir

Image: The Tribune, Online Edition, 25 August, 2009

Watermills, one of the most prominent indigenous technology are in use in the Himalayan region since time immemorial and existing even today. The Himalayan region has a rich ancient tradition for tapping hydro-energy from the hill streams and rivers through the device of watermills. The watermills popularly known as 'gharats' in Himachal Pradesh, have traditionally been used for rice hulling, milling of grains and other applications.

Sankhri near Dehradun

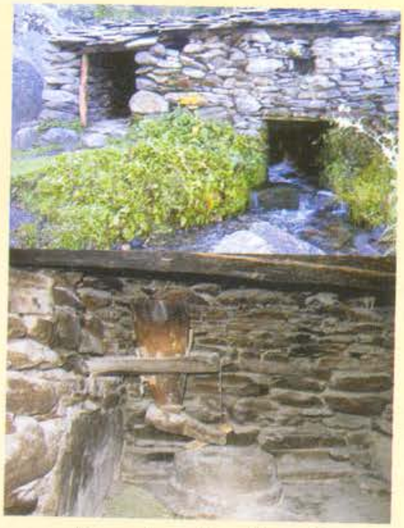


Image by : Ajeet Dyondi

The widespread use of watermills and their popularity owed much to their simple and cost-effective mechanism. According to one estimate, there are nearly 200,000 watermills in the Himalayas from Uttaranchal, Himachal Pradesh, Jammu and Kashmir to the northeastern states of the countryand many thousands more in Nepal, Pakistan, Myanmar etc. In Uttaranchal alone there are about 70,000 watermills and 50% of which are in use at present. As mentioned above the design of traditional watermills is centuries old. Their low output (5–10 kg of flour per hour) does not provide enough profit to the owners today. In recent years, watermills have thus started to fall into disuse. This is probably also because they were serving only the remote rural communities of the Himalayan region and their potential remained hidden or was neglected. In the absence of appropriate technology, watermills were not used for any purpose other than grinding wheat, maize, and rice. The importance of watermills was further overshadowed by the introduction of diesel and electricity powered mills, and theinclination of the people towards high-speed grinding machines. Moreover, owners of traditional watermills were often forced to descend to the plains to seek more lucrative employment. They were unable to do anything to save their watermills. Moreover, the insufficient flow of water and seasonal variation in recent past has forced to close down such traditional mills.

Pakistan

Image by : Karl Schuler

Bhutan

In the 19th Century, the technology improved further and millers started using the shaft to drive multiple other shafts though gears and started using them for multiple functions using different gear ratios. In the early part of the 20th century, industrialization had started coming in and large hydro electricity projects. Cheap electricity from these large projects made these mills obsolete. The large factories started producing flour at a much cheaper rate added to the misery to the water flour mills.

Adequate efforts have not been made to harness the water resources that originate in the Himalayan region in order to address the increased need for small-scale energy for local use and sustainable livelihoods among the population living in remote and inaccessible mountain areas. Most of these areas are still without electricity, which plays a vital role in the development of any society. There is a need to ensure that local communities can benefit from energy just like people in

Nepal

Image: Centre for Rural Technology, Nepal

Afghanistan

Image: Remote Hydro Light, Kabul, Afghanistan

Tibet

Image by Antoine Taveneaux

the plains: they need to be empowered to tap and make the best use of local water resources, based on traditional technology to do this and improvement of time-tested technologies for better efficiency. This will allow them to produce added value and enhance their livelihood options.

These water mills or Gharats are of the vertical shaft type, evolved over thousands of years and are used essentially for grinding wheat, rice and maize and also to extract oil. Due to lack of technology they have not been upgraded to produce electricity. Assuming that each one of these mills generate only 5 KW, collectively they would generate 2500 MW of power and employment to 15 million people. With a little modification the power generating capacity could be much more.

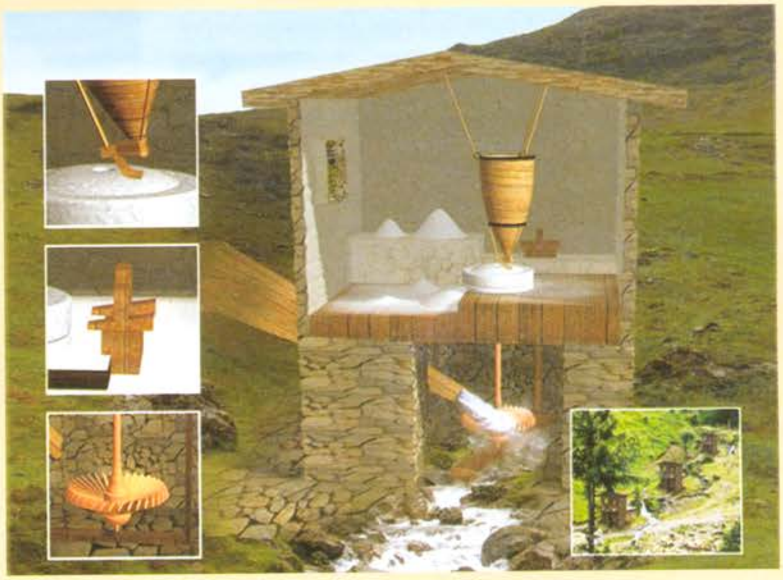
The most elementary use of hydropower in the Himalayas has been in the traditional watermills (or gharats) for grinding grain. The widespread use of gharats and its popularity owes much to its simple and cost-effective mechanism. Uttaranchal, in Indian Himalayas is a mountainous state with rugged terrain. There are several perennial streams, rivulets and rivers in this part of the country where in traditional watermills (or gharats) located at the bank of these streams and rivers have been the parts of villager's life and used as important source of energy from centuries for grinding their food grains. As the low efficient traditional water mills could not cater the increasing processing needs of people, diesel mills are entering in the potential areas. Many of these are currently being abandoned by the water millers for better income generating opportunities and the existing ones face stiff competition from the diesel mills.

In the olden days, possession of Gharat as an important item of household was not only a significant achievement of the family but also a matter social prestige and pride. The owner of Gharat in those days happened to be a socially dignified and a rich person. He was given privilege of a person with distinct social status. Among the Rawain community of Uttarakhand and Himachal Pradesh, the socio-economic status of a person who owned Gharat in those days was given due regards by the villagers and the neighbouring communities.

Appropriate site where perennial sources of water are available could only maintain or run a mill. Therefore, the owner of that land in most of the cases runs Gharat to meet the requirement of the village or surrounding community. This was perhaps the reason that owner of Gharat among the Rawain community occupied a respectful position in their society.

Construction of Watermills

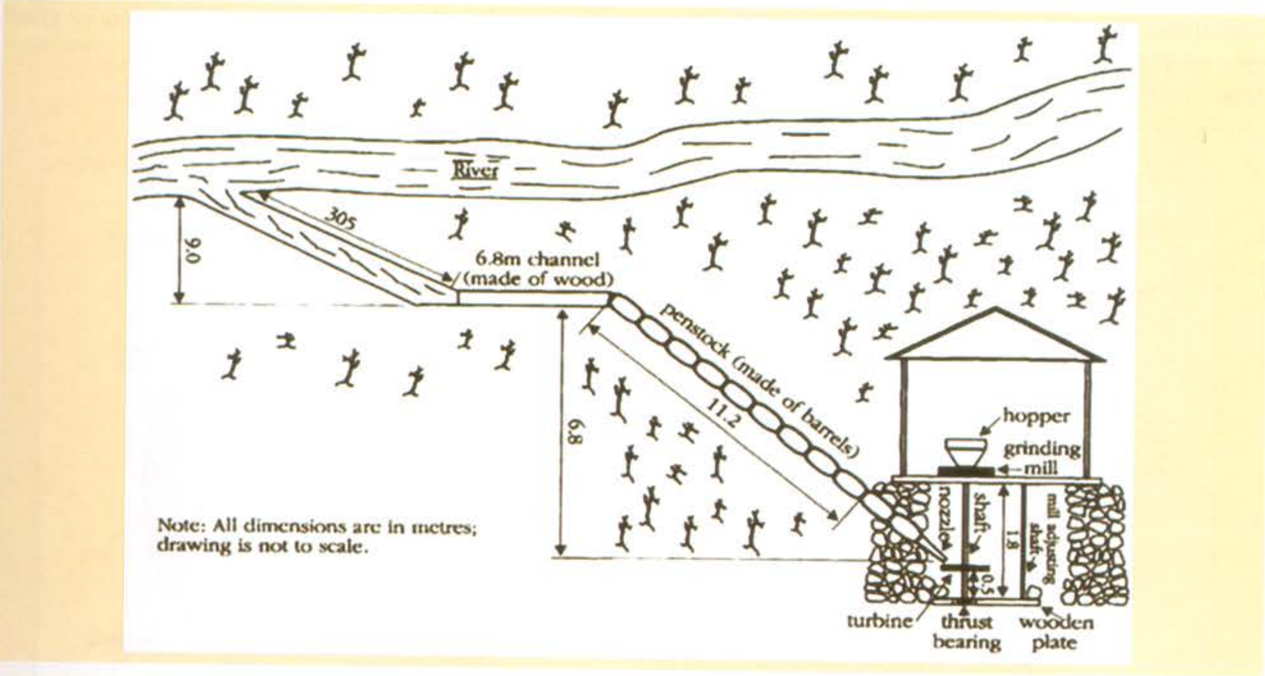
Natural sources of water available in these undulating hilly terrains that are flowing turbulently through out the years are used for operating the mills. The simple devices used in running the mill are locally manufactured by the folk and rural people who inhabit in this region. Installations of these kinds of traditional mills are mostly found to the site where perennial source of water is available.



3D Max image of a typical ▸ Gharat of Uttarakhand

(Drawn by Sayantam Sengupta)

These running streams carrying large volume of water is managed to pass through a canal locally constructed at an elevated point from where water can be dropped with desirable amount of force. From this elevated point, a long wooden canal is mounted in an inclined position allowing the water to fall and hit the blades of wooden turbine.



Note: All dimensions are in metres; drawing is not to scale.

A typical layout of a watermill

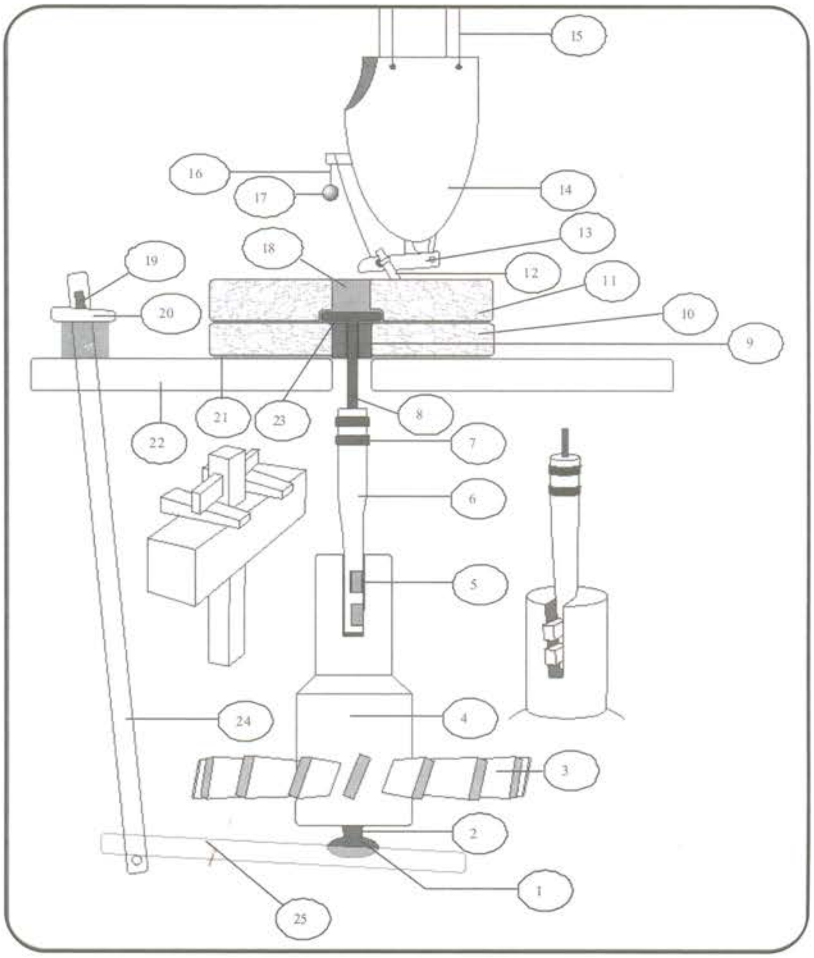
Jhaleri (wooden turbine with multiple wings or blades)

Image: Mountain Research and Development Vol 26 No 2 May 2006

This wooden turbine contains multiple wings/blades and it is positioned in a manner that the lower end of the wooden canal faces the blades. When water hit the blades of wooden turbine, it starts rotating and further allowing the entire parts of the devices function as a mill, which is unique of its kind. Interestingly, all these simple devices work very efficiently.

The traditional Gharat used in the Gundigaon village of Uttarakhand has not been replaced by any kind of mechanical innovations. It consists of wooden parts like Panyala (wooden canal), Jhaleri (wooden turbine with multiple wings or blades), Ghate(grinding stone), Chada(wooden and iron lever with gear), Reedi(wooden funnel used to stuff grains for grinding) etc. and all these tools work with their elaborate mechanical functions allowing the grains to grind simply by using the engergy of water.

Fast flowing water is collected at an elevated point from the low lying shed of Gharat. The water is then droped down by Panyala inclining to that level which can give sufficient amount of energy to rotate the turbine and the big size upper wheel of stone. The water wheel, so call Jhaleri is interconnected through a wooden lever that gives mechanical energy to rotate the stone grinder. Another shaft of lever (excelled with wooden or iron gear), fixed near the rotor is vertically mounted to propel and adjust the upper portion of grinding stone. This lever is mainly used for adjusting the stone wheel (grinder) to lift up and down so that the grains could be grinded either in coarse or fine manner. A funnel shaped Reedi with Lalthou (controlling knob) is mounted vertically above the stone wheel grinder for pouring desired quantity of grains. The grains that are stuffed inside the Reedi gets passed on to the centre hole of the stone grinder only after the controlling device called Lalthou gets vibrated with the friction of grinding stone wheel. When grains are droped uniformly into the cavity of grinding stone, it subsequently gets crushed with the stone wheel resting at lower portion of the rotating Ghate. The grinded cereals ready for consumption are than collected and distributed to the concern person who came to grind their cereals or grains.



Detail of parts definition of a traditional water mill

1. Stone socket
2. Stone pivot
3. Vanes (Jhaleri)
4. Crown
5. Wedges
6. Upright Shaft
7. Iron Rings
8. Stone Spindle
9. Wooden Boss
10. Bed Stone
11. Runner (Ghate)
12. 'Damsel'(Lalthou)
13. Shoe
14. Hopper (Reedi)
15. Rope
16. Cord
17. Check Weight
18. Eye
19. Teeter Yoke
20. Wedges
21. Layer of Clay
22. Floor
23. Rind
24. Tentering Rod
25. Sprattle Beam

Millstone Nomenclature

Millstones come in pairs. The base or bedstone is stationary. Above the bedstone is the turning runner stone, which actually does the grinding. The runner stone is supported by a cross-shaped metal piece fixed to a "mace head" topping the main shaft or spindle leading to the driving mechanism of the mill.

The Basic Anatomy of A Millstone (runner stone)

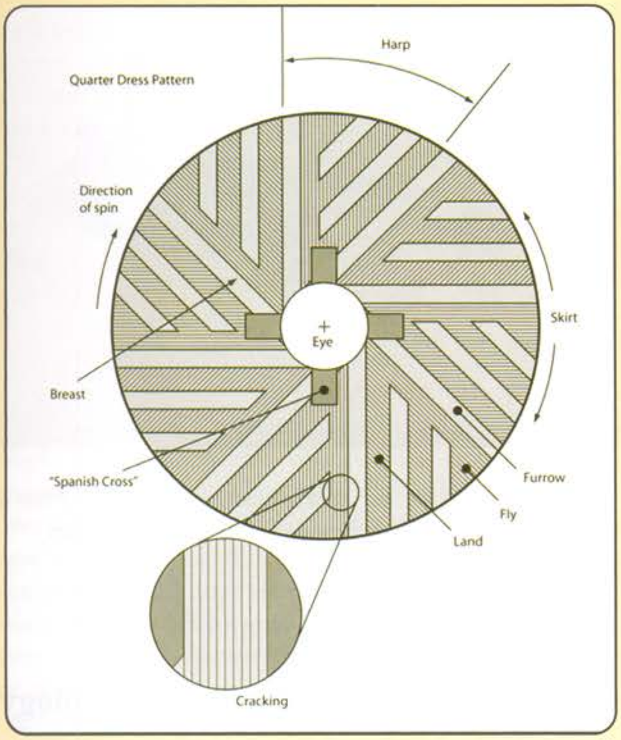
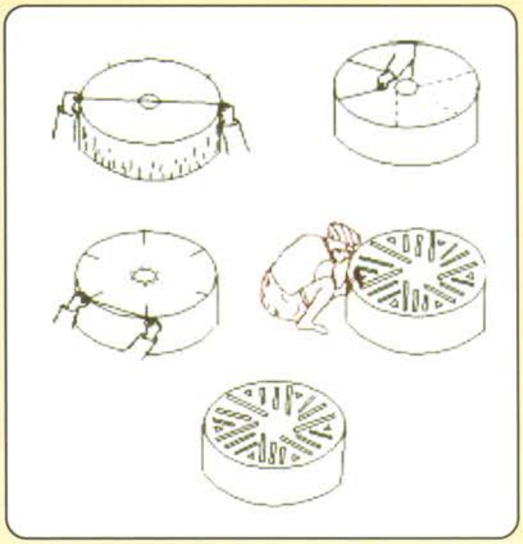


Image: Millstone Anatomy by Stevegray, March 2006

Steps of Dressing of Grinding Stone



Dressing of stones is very important to increase the output of the water mills. Stones grooving are necessary to be made scientifically. It is very necessary that grooves should be maintained time-to-time and proper.

Image: Alternate Hydro Energy Centre, Indian Institute of Technology, Roorkee

The pattern of harps is repeated on the face of each stone, when they are laid face to face the patterns mesh in a kind of "scissoring" motion creating the cutting or grinding function of the stones. The surface of a millstone is divided by deep grooves called furrows into separate flat areas called lands.Spreading away from the furrows are smaller grooves called feathering or cracking. The furrows and lands are arranged in repeating patterns called harps.

A typical millstone will have six, eight or ten harps. The grooves provide a cutting edge and help to channel the ground flour out from the stones. When in regular use stones need to be dressed periodically, that is, re-cut to keep the cutting surfaces sharp.

Millstones need to be evenly balanced, and achieving the correct separation of the stones is crucial to producing good quality flour. The experienced miller will be able to adjust their separation very accurately.

A blacksmith shaping a new grindstone for an updated water mill in the Himalayan state of Uttaranchal
Image: IT Power-India (ITPI)

Portrait of an old man dressing a Millstone (From the collection of the Smithsonian Institution) 19th century

Validation of Traditional Water Powered Mill as Appropriate Technology

It is felt that an urgent need to intensify the efforts to raise the concern levels, improve the opportunities and options of livelihood based on people's knowledge systems and build up an environment to promote the inclusion of this knowledge system in the development process, to improve its efficiency, effectiveness and sustainability, which is particularly potent in the region.

Many of traditional and /or local systems of water-collection, storage, and development and management of water-resources, unfortunately, fell into disuse with the onset of 'modernisation' during the colonial period.The system came to an end after the advent of the British. Elsewhere too, the traditional methods were over-shadowed, reduced in status, or openly discouraged due to the invasion of 'Western' technology. The situation did not alter with the coming of Indian Independence, and the process has continued into the late 20th Century, with a basic reliance on big dams, inter-basin transfers and surface transport of water through canals and watercourses. Fortunately there has been a revival of interest in traditional water systems in recent years, both for theoretical and practical purposes, especially by development activists, scientists, environmentalists and many others associated with the cause of sustainable development. Issues emerging from the debate on environmental protection and community empowerment have resulted in a strong need to have a fresh look at these older and time tested practices and utilize their benefits for meeting the present day needs of rural and urban areas.

Appropriate Technologies are small-scale, more labor intensive than capital intensive, culturally relevant, and sustainable technologies appropriate for particular environmental conditions, social contexts, and economic situations. It also includes the recognition that technologies can embody cultural biases and sometimes have political and distributional effects that go far beyond a strictly economic evaluation. Appropriate Technologies are not appropriate for all situations, but are more about local people using local knowledge and resources to meet their needs without compromising the ability of future generations to do the same. Therefore it involves a search for technologies that have, for example, beneficial effects on income distribution, human development, environmental quality, and the distribution of political power in the context of particular communities and nations.

The importance of peoples' knowledge is being increasingly recognized the world over and there is many reasons for doing so. The living knowledge or the wisdom which people have gained and developed through years of careful observation, experience, experimentation and adaptation has helped them survive and secure their livelihoods in the difficult and unique biophysical conditions of the mountains. It is undeniably ironical that despite being an invaluable resource there has been a gradual loss of faith of people in their own knowledge system and practices, and at the same time there has been its increasing recognition at the global level.

Decreasing faith, lack of documentation, severe competition from highly promoted and subsidized products etc. as well as the growing globalization of markets and appropriation of resources and knowledge by global forces is leading to a gradual erosion of knowledge. And the tragedy of its depletion is most obvious to those who are dependent on it and do not have access to cash income to eke out an existence, i.e. the most marginalized and excluded in the society. Having played a crucial role in the survival of people especially the marginalized groups, in harsh but vulnerable conditions, it holds great potential but also faces innumerable challenges.

With the intervention of modern electrical and fuel-operated mills, the use of Gharat in this mountainous region declines to the level of extinction. It is important that such kind of traditional devices which are sustainable in all its forms need properly documented and preserved as an important asset of Himalayan Culture.

Therefore, there is an immediate need to act on popularization and dissemination of knowledge of our age-old traditional technology and the initiative taken to revive and implement the modification towards the appropriate technology for self-reliance of the marginalized hilly community to overcome the impediments to implementation of the revival and revamping programe to make 'gharat' a symbol of changing lives in hills.

The potential of this traditional technology of waterpower has got relevance even in present context. The study of this traditional technology is not just an abstruse study but has also direct relevance to the socio-economic and environmental problems of Himalayan regions of Uttaranchal and Himachal, as also of the Southeast Asia at large.

This traditional water power technology will not only improve livelihood prospects and opportunities but also empower people- the holders and users who happen to be mostly women and the marginalized, it being within their access and control - in areas pertaining to food security, natural resources and other vital economic and social activities, their active participation in development dialogue and also mainstreaming People's Knowledge into the overall development process.

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Historiography of Plant Taxonomy in India

Niranjan Gupta

Abstract

India's tradition in science is not only ancient, but also very extensive and varied. The awareness of plant taxonomy existed in Indian subcontinent from the very beginning in ancient forms when knowledge of science used to be disseminated through the traditional way of oral narration. The seminal works in plant taxonomy can actually be traced back to ancient India.

The study provides specific references to establish the fact that pursuit of plant taxonomy already existed in ancient India. Historic and literary evidences suggest that the science of classification and nomenclature of plant were already present in ancient India. It was the base of different branches of science like Herbal medicine, Anatomy, Physiology, Agriculture etc.

We have enough literary evidences which suggest that study of plant taxonomy originated in 250-200 BC. Theophrastus and Aristotle are the acknowledged names in this field. But historic evidences pinpoint that Parasara's Vriksayurveda is one of the oldest works on plant taxonomy. Rig-Veda, Manusmriti, Charak Samhita and Susuruta Samhitas substantiate wide culture and understanding of plant taxonomy in ancient India.

These classifications are based on comparative morphology of plants. With this origin, we find that this branch has changed its form. The journey begins from herbs, shrubs, and trees and ends at oil yielding fibres. It started from the natural system, but finally culminated to artificial system and today, its base is phylogenetic or microscopic study. A lot of literary materials on the subject were available in ancient India, but several foreign attacks on India mostly destroyed them, leaving back only a few for our study.

Introduction

The relationship between human and plant began in the prehistoric time. India had been inhabited by man almost from prehistoric times, and since then he hunted to acquire knowledge of his immediate surroundings, partly for his survival and partly for his inborn curiosity. The Indus valley people lived in villages and towns. They used to cultivate crops like wheat, barley, millet, dates, melons, vegetables and other fruits and cottons, worship trees, glaze their pottery with the help of plant juices and finally paint them following many plant designs. The excavated seals of the Indus valley civilization in some parts of India indicate the presence of Ficus religiosa, Ziziphus mauritiana etc. which were used in one form or the other.

Taxonomical Studies during Ancient & Vedic Period in India

Early examples of plants taxonomy occur in Rig-Veda that divides plants into Vriksa (tree), Osadhi (herbs useful to humans) and Virudha (creepers), which are then further sub-divided. The Atharvaveda divides plants into eight classes – Visakha (spreading branches), Manjari (leaves with long clusters), Sthambini (bushy plants), Prastanavati (which expands), Ekasrnga (those with monopodial growth), Pratanavati (creeping plants), Amsumati (with many stalks), and Kandini (plants with knotty joints). The Taittiriya Samhita classifies the plants kingdom into Vriksa, Vana and Druma (trees),Visakha (shrubs with spreading branches), Sasa (herbs), Amsumali (a spreading or deliquescent plant), Vratati (climber), Stambini (bushy plants), Pratanavati (creeper), and Alasala (those spreading on the ground). Manusmriti also proposed classification of plants into eight major categories. Charaka Samhita, Susruta Samhita and the Vaisesikas also present an elaborate Plant Taxonomy.

The most celebrated plant that has frequent mentions in the Rig-Veda and later Samhitas is Soma plant. The Indians of Vedic age hail Soma as the lord of forest (Vanaraja). The botanical identity of Soma plant, however, has not been decided till today. The probable genuses are Ephedra (a Gymnosperm), Sarcostemma (flowering plant) and mushroom (a fungus).

The plant that comes next is Peeple or the Asvattha (Ficus religiosa) of the Vedic period. The Rig-Veda refers to utensils and vessels fashioned out of the wood of the Asvattha tree. Some of the other trees that find mention in the Vedas are Silk cotton (Salmalia malabaricum), Khadira (Acacia catechu), Simsupa (Dalbergia sissoo), Vibhitaka (Terminalia bellerica), Sami (Prosopis sp.), Plaksa (Ficus infectoria). Iksu (sugarcane- Saccharum offcinarum) is mentioned as a cultivated plants in the Atharvaveda, Maitaryani Samhita and other texts. The Vedic Indians knew many flower-bearing and fruit-bearing plants like Palasa (Butea monosperma), two varieties of lotus – white(Pundarika) and blue(Puskara), white lily (kumuda), cucumber (Urvaruka), Jujuba (Zizypus jujuba), udumbara (Ficus glomerata), kharjura (Phoenix dactylifera) and Bilva (Aegal marmelos) etc.

Written records, in the form of manuscripts, are available in Sanskrit and several other Indian languages. Sanskrit literature includes the Vedas, the Upanisadas, and epics like the Ramayana and Mahabharata. The lay literature includes prose, poetry, and drama written by a number of Sanskrit authors like Kalidasa, Magha and Bhabhuti, where the information of plants is incidental and given by way of comparison. Technical literature comprises medical works like the Charaka and Susruta Samhitas, lexicons like Medinighantu and Amarakosa, as well as the encyclopedic works like Arthsastra and Brahatsamhita. In addition, there are a number of exclusive works under the title of Vriksayurveda. Parasara's Vriksayurveda, composed during the first century BC to first century AD, is supposed to be the most ancient work in actual botany. From the literary evidence, it is clear that even in the first millennium BC, Botany was fully systematized and taxonomy well developed.

Sophocles (505-495 BC) mentioned rice, sandalwood etc. specifically as Indian products which were known to the Greeks only by their Tamil names. There are several words of Indian origin as plant names in Greek; for examples Arise and Vetiver in Tamil became Oryza and Vetiveria respectively. Injiver and Elathari in Malayalam became Zingiber and Elataria respectively. Sandanam (Chandanam) and Sarkare became Santalum and Sacchrum respectively. Among flowers, the sacred lotus (Nelumbo nucifera), used to wreath over the head of Sun-god, was the most popular. Plants were classified into two categories – (i)wholesome and good to eat and (ii)unwholesome or harmful.

The binomial system of nomenclature was also followed : for examples, Bala is the modern genus Sida and the specific names are suffixed to the generic names. In Sanskrit on the other hand, the specific names is prefixed to the generic name. Atibala= Sida rhomlifolia, Naga bala = Sida spinosa etc.

Economic plant products of India like Cardamom, Black Pepper, Ginger, Cinnamon, Sugarcane, Sandalwood, Rosewood, Turmeric, Indigo etc. were known in various parts of the western world as oriental luxury several centuries before the birth of Christ.

Taxonomical Studies from pre-British to post-British period and modern India

I.H. Burkil (1965) in his book "Chapters on the History of Botany in India" has mentioned the history of modern development of Botany in India, which until the beginning of the 20th century was almost exclusively concerned with exploration and systematic Botany of higher plants over the four centuries beginning with 1500 AD. Natural Science, commonly known as Botany, was introduced in India as an exotic system of knowledge. In the beginning of the 16th century, Botany emerged out as the science or technique of healing in particular part of Europe.

The classical Greeks had been conspicuous in the healing art. Then came the Arabians, who from Baghdad reached out to the Indus during the reign of Khalif Al Mansur" (745-775 AD). They translated Charaka Samhita and the Susurut Samhita from Sanskrit to Arabic and Persia.

Later Vasco da Gama also rounded the Cape of Good Hope and anchored Calicut (Kozhikode) on 29th May 1498 by his 10 months and 12 days voyage from Lisbon. In addition to interest in spices and other luxury items from India, the shortage of wood on the shores of the Red Sea also was another important factor for the growth of Portuguese possessions in India and remained so till December 1961, when it was annexed to the Indian union.

A physician and pharmacist named Garcia de Orta (1490-1570 AD) came to Goa from Elva's to study native drugs and their uses. He published his work in a book called Coloquios in the year 1563 in which a detailed account of 57 more commonly used Indian medicinal plants were described. The book became known to Europe mainly through the Latin summary of Clusius published in 1567.

Van Rheede Drankenste, the Governor of Dutch Possession in India, started publication of his monumental Hortus Malabaricus, an illustrated account of the floristic resources of the area, for the exploitation and benefit of all. Live plants from Cochin and its neighborhood were brought, illustrated and described; the accounts were finally translated into Latin. The manuscript was prepared at Cochin and sent to the Netherlands.

The first volume of this great collaborative work was published in 1678 under the title Hortus Indicus Malabaricus. The next 11 volumes were also published from Amsterdam. In these volume, there are 794 excellent illustrations covering about 780 species. When Van Rheede was organizing the work on Hortus Malabaricus, the English had very good relation with the Dutch and inspired by latter, the English also began collecting plants in the Madras coast with the help of the captains of ships and others connected with East India Company. Among these English collectors, special mention may be made about James Petiver, Charles Du Bois, an official of East India Company.

In 1697, Leonard Plukent (1641-1707 AD) began to publish copper-plate illustration of plants under the Phytographia. Petiver also began publishing reports of the plants. The plants possessed by Plukenet and Petiver ultimately reached the British Museum. The Pre Liumean inquiry into the Flora of India ended with Petiver.

In the 17th and first half of 18th century, there were no generally accepted rules for naming the plants. Linnaeus species Plantarum (1753) and Genera Plantarum (1754, 5th ed.) marked a new epoch in botanical history. In Species Plantarum, he consistently used the binomial nomenclature. The description of Genera Plantarum is accepted to validate names.

The beginning of Post-Linnaean Botany in India may be said to date from the arrival of J. G. Koenig, a pupil of Linne, in 1768. Koenig joined the Tranquebar Mission as a surgeon and naturalist, and in union with some of United Brethren such as Klein, Rottler, etc, made splendid collection in the neighbourhood of Madras; the Brethren sent their specimen to various botanists in Europe. There was also a botanical Garden Tranquebar in around 1768. Moravian brothers were awarded the contract to sell dried plants to Joseph banks and carried out their promise from 1775 to 1778. It was from this transaction that an idea of starting a learned society of Botanists at Madras came up and "United Brothers" by name, was formed in 1775.

In Bengal, the earlier works on Botany were associated with Johan Fleming, Sir William Jones, Roxburgh, Wallich, Buchanan-Hamilton, etc. In 1787, Robert Kyd founded the Botanical Garden of Calcutta, and from the very beginning, it has occupied a pre-eminent position in the development of botanical studies in India.

The initial progress of Botany in Bombay was associated with the names of Alexander Gibson, John S. Law, J. E. Stocks and Johan Graham. Bombay can boast of being the first province in India to have a Conservator of Forest, Mr. A. Gibson (1847), whose main duty was to put a stop to the wasteful destruction of forests within the province.

In North and North-West parts of country, the name of J. F. Royle stands out prominently. He did some exploration works in the neighbourhood of Saharanpur Botanical Garden and in the Himalayas. Other early explorers in the North-West are W. S. Webb, William Moorcroft, Alexander and James S. Gerard, Henry Strachey, Richard Strachey etc. Many of their collections were gathered at the Saharanpur Botanical Garden (later transferred to Dehra Dun), and Royle based his splendid illustrations on these collections as well as his own.

In Madras, commendable works in Botany were done by the Tranquebar Brethren, Roxburgh (at the beginning of his service in India) and by Robert Wight. Wight has been rightly called the greatest collector of plants during his time. He was indefatigable in his field tours in the northern parts of Madras, Tanjore and later in other parts of South India, and also in the publication of most magnificent books, which are indispensable to any serious worker in Botany even today. During his 35 years of stay in India, Wight described 38 new genera and more than 3000 species. His contributions include

28 publications, amongst which "Illustrations of Indian Botany" (1831-1832, 1840 and 1850) is worth mentioning.

In 1855, Sir J. D. Hooker and Thompson published the first volume of "Flora of India". But this work was soon given up in favour of more comprehensive publication "Flora of British India", which started in 1872 – the seventh and last volume came out in 1897. Although, the work was a pioneering one, yet Hooker himself acknowledged that in a work of this scope, neither fullness nor completeness is attainable in the present state of science. In spite of such incompletenes, "Flora of British India" is considered a monumental work reflecting the ingenuity and diligence of Hooker and his assistants, and has formed the basis of all later provincial publications.

From the inception of the Indian Botanical Garden, a new era of Botanical research began. This garden has been a centre of intense activity in the taxonomic study of plants. The Herbarium contains the most valuable collection of plants from India and adjacent countries – many types of Indian plants were carefully preserved there. On account of a large number and varieties of specimens (calculated as several millions), the Herbarium forms the most valuable nucleus of Botanical specimens in India, and deserve due attention from Indian Botanists.

Effort was made to fulfil the plan of having publications on floras of various peninsular provinces that did not have them. Intensive exploration went on all over the country under the initiative of Botanical Survey of India with little help from the universities. The latter seemed to be more attracted towards other branches of Biological Sciences, such as Embryology, Physiology etc. As a matter of fact, after the closure of Botanical Survey of India, plant taxonomical work in the country got a set back and practically came to a standstill. A few centres of activity, although, kept on continuing their work in spite of difficulties.

Calcutta has continued to be at the head of Systematic Botany in the Peninsular India in this century, as it was also during the previous one. At the beginning of the century, D. Prain published his book on Bengal plants and made several important contributions. The records of Botanical Survey of India were brought out in 16 volumes. The annals of Royal Botanic Garden, Calcutta, were published in 6 volumes between 1900 and 1950, the latest being on Dioscorea by I. H. Burkil and D. Prain. The successive superintendents of Botanical Garden and their assistants have kept up the traditions of the Garden in spite of acute shortage of fund and manpower.

In 1915, J. S. Gamble published the first part of his "Flora of Madras" and at the outset, the book was received in the botanical world as one of the best works on the floras of India. Gamble supervised the publication of the first seven parts. After his death in 1925, C. E. C Fischer, who had done intensive study on the flora of the province, completed the work in 1936. P. F. Fyson studied the flora of Nilgiris and other high hills of South India. In 1929, P. V. Mayuranathan brought out a publication on flowering plants of Madras city and its immediate neighbourhood. This was one of the best books on local or restricted floras of this century. In 1938, E. Barnes published a supplement to Mayuranthan's book. During the last few years, great commitment has been shown by a school of young and energetic botanists of Bangalore and Mysore. It is hoped that their enthusiasm will not fade until the flora of Mysore is fully known.

With the establishment of the southern circle of Botanical Survey of India at Coimbatore in 1955, floristic studies under their jurisdiction were intensified. Over 325 research papers dealing with about 75 new texa and 360 additional records for the area have been developed.

Subramanyam Sebastine and their colleagues explored intensively in several parts of the country. Scientists from other units of BSI, particularly from Calcutta also collected specimens in Tamil Nadu during the period. K. S. Srinavasan and T. A. Rao collected plants of the coastal regions of Tamil Nadu. Workers other than those of BSI were also engaged in floristic work. Rapinat Herbarium, Tiruchirapally is a centre of intensive floristic activity. Here, Fr. K. M. Matthew and his colleagues have worked and added much to our knowledge of plants of Tamil Nadu. Matthew brought out materials for publication of "The Flora of Tamilnadu Carnatic" (1983) in 3 volumes, Flora of Palni Hills (1996) etc. Dr. T. Senthil Kumar and K. V. Krishnamurthy of the Bharathidasan University carried out extensive research work on Ethnobotanical study on Shervaroy Hills of Eastern Ghats. A number of staff of the Calicut University studied the plants of Manilal in Northern Kerala and published the "Flora of Silent Valley"(1988). The Kerala Forest Research Institute (KFRI), Peechi is another ideal centre for floristic activities with its publication "Flowering Plants of Kerala"(2004). Tropical Botanical Garden & Research Institute (TBGRI), Palode, Trivandrum is also playing a very vital role for plant taxonomy in Kerala. The institute concentrates, especially on the plants growing on Agasthyamala hills and some small islands of Kerala. "Flora of Kerala" is a good database of about 4000 flowering plants of Kerala for the last five years, being published by TBGRI.

In Andhra Pradesh, publications worth mentioning are "Flora Andhrica" (1859) by W. Elliot , "Forest Flora of Hyderabad State" (1953) by S. M. Khan, "Flora of Andhra Pradesh"(1997) by Pullaiah & Moulali and "Flora of Visakhapatnam District, Andhra Pradesh" in 2 volumes by G. V. Subba Rao and G. R. Kumari.

The Forest Research Institute, Dehra Dun has been one of the most active centres in India. Botanists have extended and spread their work all over the country through similar institutes. Notable contributions have been made to the flora of the Upper Gangetic Plain and other parts of Northern India by J. F. Duthie, R. N. Parker, C. E. Parkinson, M. B. Raizada, N. L. Bor and others.

At the beginning of the century, Pune was the centre for Botanical explorations in the western parts of the country. Outstanding works were done by T. Cooke, G.A. Gammie, R. K. Bhide, G. M. Woodrow etc. W. A. Talbot concentrated his works on the forest flora, particularly that in Bombay Presidency. Plants of Northern Gujarat were explored by W. T. Saxton and L.J. Sedgwick. Sedgwick also made extensive collection in Dharwar. G. L. Sha of Sardar Patel University, Vallabh Vidhyanagar and his students explored several parts of Gujarat and published many records. He also published the Flora of Gujarat in two parts (1978), which also has elaborate bibliography. In Bombay itself, E. Blatter formed a school of systematic Botany, and together with his pupils, made extensive exploration in various parts of the province. Bombay can boast of Jayakrishana Indraji Thaker, who after long apprenticeship in Bombay went to Saurashtra and explored the Barda hills. His results are embodied in a monumental book, the first scientific book on systematic Botany written in a regional language (Gujarati) in India.

Theodore Cooke (1836-1910) came to India in 1860 as Railway Engineer and later became the Principal of Civil Engineering College, Pune. He was also attached to the Agricultural College from where he studied the plants of Bombay Presidency. Cooke published the first volume of the "Flora of Presidency of Bombay" in 1901 and the second volume in 1908. These volumes were reprinted with some corrections in 1958 by the Botanical Survey of India. Cooke's flora also covered Sind, Gujarat and North Karnataka.

The next botanical period in Maharashtra was led by Rev. Ethelbert Blatter (1877-1934), a Swiss Botanist, who did a great deal of field work. He was the chairman of Biology Department, St. Xavier's College, Bombay.

H. H. Haines did much work in Chota Nagpur plateau in Bihar and Orissa. His work was continued by H. F. Mooney, who recently brought out a comprehensive supplement to Haines Botany. At present, there is a great interest in the study of the vegetation of Madhya Pradesh, and the preparation of regional flora is well advanced. Botanical Survey of India published "Flora of Madhya Pradesh" in 1997.

The last of the great provincial floras came out in Assam. It took a big team of botanists, under the energetic direction of U. N. Kanjilal, several years to bring out the series of volumes on *Flora of Assam*. Independently, C. E. C. Fischer has published a number of papers on Assam novelties; N. L. Bor has done very good work on the grasses of the province. Assam, however, still has many districts of which the botany is very little known.

The latest developments in the study of systematic Botany are very encouraging. The world, at large, and our own national laboratories, in particular, have come to realize the great dependence of many branches of science on raw materials from the plant kingdom. One of the visible signs of interest in systematic Botany is the growing attention paid by our universities. Of late, papers have been received from the universities of Benaras, Annamalai and Allahabad in India and also from Rangoon in Burma and Karachi and other universities in Pakistan. Intensive work also goes on in some of the best universities of the various countries under the survey. Thus, we see that the ancient scientists did realize the need to classify plants according to their various properties. In some cases, they come close to modern classification.

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